Circuit Court of the United States,

DISTRICT OF MASSACHUSETTS.

IN EQUITY.

No. 1,628.

AMERICAN BELL TELEPHONE COMPANY

v.

AMOS E. DOLBEAR ET AL.

EVIDENCE FOR DEFENDANTS.

TAKEN PURSUANT TO THE SIXTY-SEVENTH RULE OF THE SUPREME COURT OF THE UNITED STATES, IN EQUITY, AS AMENDED.
BEFORE ME,
WILLIAM A. COPELAND, *Special Examiner.*

BOSTON, May 4, 1883.

Present: J. J. STORROW, Esq., *of Counsel for Complainants;*
J. E. MAYNADIER, Esq., *of Counsel for Defendants.*

DEPOSITION OF AMOS E. DOLBEAR.

Direct Examination by J. E. MAYNADIER, Esq., *of Counsel for Defendants.*

Int. 1. What is your name, and are you one of the defendants in this case?

Ans. Amos Emerson Dolbear; I am.

Int. 2. What has been your occupation for several years past?

Ans. I have been professor of physics for the past nine years at Tufts College.

Int. 3. Please state what physical laws are concerned in the transmission of sounds.

Ans. Physically, sound consists in all cases of such vibratory motions as are competent to produce the sensation we call hearing. There must therefore be some means for producing such vibrations, and some means for transmitting them As to production, some body must be made to move in a proper way, which, of course, requires the expenditure of energy upon the body which is to move.

Generally, the appropriate movement is a vibratory one, and then the energy is known as vibratory, or the energy of vibration.

If this vibrating body is in connection with another body possessing elasticity, the latter will receive and transmit throughout its mass that same vibratory movement.

For example, when I speak I expend energy upon the vocal organs. The air in the passages leading from the vocal organs is made to vibrate because in contact with them, and thus the vibrating movement is propagated outwards in every direction, and is rapidly dissipated.

If I permit the air vibration to fall upon a sheet of paper near my mouth the paper will be made to vibrate, and a string or wire may receive the vibrations of the paper and transfer them to the distant end, where they may be again given up to the air and so reproduced.

The string telephone is a familiar example of such transmission and reproduction. The energy which may be called physiological at first is transformed into vibratory mechanical energy in the vocal organs and is easily dissipated in free air, but when expended upon the tympanum of the string telephone is concentrated upon the wire by which it is transferred as vibratory molecular energy which is again transformed into a mechanical and then to an aerial vibratory energy at the receiving end.

Sound may be transmitted without any change of medium, and this may be called direct transmission as distinguished from any method involving a change in the medium; but if by transmission of sound is meant the production in an indirect way of air vibrations in one body of air, similar to those produced in another body of air by employing the energy of the latter to produce the former, then the string telephone would be a type of all means for accomplishing that; for the energy of certain air vibrations is spent upon a device which may be called a transmitter, the function of which is to transmit that energy with as little change as possible to a second device, the connector or transferrer, the function of which is to transfer to its farther extremity the energy it has received from the transmitter with as little change as possible, and then to deliver to a third device called a receiver, whose function is to produce undulations in the second body of air similar to those produced at the transmitter.

Int. 4. In all cases of the transmission of sounds, upon what does the perfection of result depend so far as concerns the closeness of resemblance between the sound-waves set up by the receiver and those which actuate the transmitter?

Ans. A perfect transmitter must have the ability to receive and transmit to the connector either directly or by transformation every variation in the mechanical energy of the sound-waves, however minute. The perfect transferrer or connector must have the ability to receive and transfer to the receiver the energy supplied to it by the transmitter without change, and the perfect receiver must be able to receive the energy supplied to it, and transform it into air vibrations. The energy of the sound-waves must be transformed as a condition of transference. Such transformed energy must have all the successive changes that characterize the original energy if it is to be employed to produce energy like the original energy. For example, suppose I wanted to transmit sound by heat. The original sound vibrations must so act upon a device as to generate heat, or to control a source of heat so that the heat generated or controlled shall correspond in all its successive changes with the successive changes constituting the original sound-waves. There would then have to be provided a conductor of heat as a transferrer, and for a receiver a device capable of receiving and transforming the varying heat energy received and transforming it into air vibrations. If in this case there was no loss or other transformation than I have mentioned, the air vibrations at the receiver will be in all respects like the original vibrations. Or, suppose I wanted to transmit light telegraphically; the radiant energy must act upon a device capable of transforming the radiant energy into electrical energy, which must be similar in form to the vibrations of the radiant energy. A suitable conductor must then be provided to transfer the electric energy to another device capable of transforming the electric energy supplied to it into radiant energy, which corresponds in all its successive changes to the successive changes of the electric energy supplied to it.

Int. 5. In what you have just said about the transmission of light telegraphically, do you think you have invented or discovered any method of or apparatus for transmitting light telegraphically?

Ans. No, I have not described or discovered or invented any method or apparatus for transmitting light telegraphically; nor do I know of any method or apparatus for accomplishing that end. I have not described the art of transmitting light. I have only described the conditions upon which the art must be founded. The conditions are such as belong in the well-known domain called "the conservation of energy," which must be followed in all cases involving energy.

Int 6. Referring to your fourth answer, where you speak of the perfect receiver, you seem to me not to have finished that part of your answer, as under your definition the receiver which made any sort of air vibrations might, I think, be included. Please refer to that part of your answer, and make it more full, if you think it important, upon reconsideration.

Ans. The perfect receiver transforms the energy it receives into air vibrations, the successive changes in which correspond with the successive changes of the energy supplied to it. Otherwise the produced sounds would not be similar to the original ones.

[*Noon recess.*]

Int. 7. Are you familiar with the Letters Patent No. 174,465, dated March 7, 1876, granted to A. Graham Bell, upon which this suit is based?

Ans. I am.

Int. 8. Please examine Fig. 5 of the drawings of that patent, and state what method of transmitting sounds is practised when that apparatus is used.

[*Objected to as immaterial.*]

Ans. In this method the mechanical energy of a vibrating body *c* is transformed into magnetic energy, the corresponding changes in which are the same as those of the body *c*. Such magnetic energy is again transformed into electric energy, which is transferred by the conductor *e g* to a receiver, where it is transformed into magnetic energy, and that into mechanical energy in the body *h*, so that the body *h* duplicates in a more or less perfect way the mechanical motion of the body *c*.

Int. 9. What was the state of the art before 1876 as to the use of two electro-magnets, the coils of which were in the same circuit, the motion of the armature in one giving rise to corresponding motions of the armature of the other?

Ans. That arrangement was well known and had been for thirty years; it being found in an old telegraphic device invented by Gauss and Weber in 1835 or 1836, fully described on pages 416–420 of this book, "Electricity and the Electric Telegraph, by George B. Prescott. With Illustrations. Fourth edition. New York: D. Appleton & Company, 1881."

[*Complainants object to the attempt to use a book printed in* 1881 *to prove the state of the art before Mr. Bell's patent of* 1876.

Defendants' counsel states that the book is not to be used for that purpose, but simply to make clear what the witness means by the Gauss and Weber method, and that copies of publications prior to 1876 *will be put in evidence at some future time.*]

Int. 10. How did this method of Gauss and Weber differ in substance from the method practised in using the apparatus shown in Fig. 5 of Bell's 1876 patent?

Ans. In the Gauss and Weber the mechanical energy applied that was converted into magnetic energy was without the periodic motion which belongs to the body *c* in this method,—Bell's method,—and likewise in the Gauss and Weber receiver the body to receive the mechanical energy in the place of the body *h* in the Bell method did not have a periodic motion or vibratory movement of its own capable of producing a sound in the Gauss and Weber method, as it has in this Bell method.

Int. 11. Of what utility is that method practised in using the apparatus of Fig. 5 of the Bell patent of 1876?

Ans. I don't know that it has any utility. It seems to be capable of transmitting and reproducing one particular kind of movement, or a sound of a particular pitch, but with very much lessened strength — too weak to be useful.

[*All of the answer after the first sentence objected to, as it does not* *appear that the witness has any knowledge or means of knowledge on the subject.*]

Int. 12. I did not intend to confine you in my question to the crude apparatus shown in Fig. 5 of Bell's 1876 patent, but desired to get your opinion as to the utility of the method, namely, the transformation of the energy of a vibrating body, such as a tuning fork, into magnetic energy, the successive changes in which copied the successive changes of the mechanical energy in the tuning fork; transforming such magnetic energy into electric energy; transferring that to a receiver, and there transforming it into magnetic energy again, and finally transforming that magnetic energy into vibrations capable of producing sound-waves, like those produced by the first vibrating body.

Ans. It is evident that I misconstrued the former question, for I supposed it referred to this specific device shown in Fig. 5 of Bell's 1876 patent. With a better understanding of the question I should say that the method might be of very great utility.

Int. 13. Please state what method is practised in using the apparatus shown in Fig. 7 of Bell's patent of 1876.

Ans. It is substantially the same method as in Fig. 5; the difference being only in this, that the energy operating to vary the magnetism is the energy of air vibrations in Fig. 7, while the energy to operate the corresponding part in Fig. 5, is energy imparted to *c* by a blow or by a violin bow, or anything to set *c* in vibration.

The amature *c* in Fig. 5 is therefore capable of but one rate of motion, while armature *c* in Fig. 7 may receive any rate of motion, and is therefore adapted to transmit and reproduce any such motion. I don't think that I can add anything to that.

Int. 14. I don't think you have been quite full enough in your description of the method practised when the apparatus in Fig. 7 is used. Please describe it without reference to any other method.

Ans. I don't think I know what you mean.

Int. 15. You described it in your thirteenth answer, by reference to the method practised when Fig. 5 was used. I shall be obliged if you will now describe the method practised when Fig. 7 is used, without reference to any other method, as I want, upon the record, a clear description of the method practised when Fig. 7 of the Bell 1876 patent is used.

[*Objected to if it is intended to put a construction upon the word "method" in the fifth claim, because its meaning is to be learned by the Court from the specification, and not from the opinion of an expert.*]

Ans. In Fig. 7 the mechanical energy of vibration of armature *c* is made to vary the magnetic energy of electro-magnet *b*, which, in turn, gives rise to a varying current of electricity in the circuit E, *e*, *g*, which electricity is transferred through *e* to *f*, where it varies magnetic energy in *f*, and that induces mechanical motion in armature *h*. The steps are the same as in Fig. 5.

Int. 16. What is the energy which is transformed into the mechanical energy of the armature *c*, and into what is the mechanical energy of armature *h* transformed in the use of the apparatus shown in Fig. 7?

Ans. The transmitting armature *c* is actuated by the energy of impact of air vibrations at *a*, and the energy of receiving armature *h* is transformed into air vibrations similar to the continuous changes in magnetism of electro magnet *f*.

[*Adjourned.*]

BOSTON, May 5, 1883.

[*Present: Counsel as before.*]

Int. 17. What is the novelty of that method described in Bell's 1876 patent practised when the apparatus of Fig. 7 of that patent is used?

Ans. The novelty consists in the employment of the energy of air vibrations to vary magnetic energy; or, to say it in another way, it consists in the conversion of the energy of air vibrations into corresponding magnetic energy, the consecutive changes in which correspond to the consecutive changes of the air vibrations which are operative; the transformation of such varying magnetic energy into corresponding electrical changes in an electric current and that varying current into magnetic changes in the receiver, which in turn is transformed into vibratory motions corresponding to the consecutive changes in the magnet of the receiver.

Int. 18. So far as you know or have any reason to believe, who invented this method, and what is its importance or utility as compared with prior methods for the transmission of sound?

Ans. I believe this method was invented by Prof. Bell. It was a new method and of the very highest importance as compared with any other methods for the transmission of sounds, for it was available in positions and under conditions where the use of the string telephone was impracticable, and it overcame the difficultes which had been met in the Reis system in a highly ingenious and effective manner, and rendered the transmission of speech possible on a commercial scale, and therefore it was a method of the highest degree of importance.

Int. 19. What, if anything, is there in the Bell patent of 1876 which describes or suggests or in any way hints at the employment of the energy of sound-waves to directly vary electric energy?

Ans. I do not think there is anything in that patent that hints as to the employment of air vibrations to vary an electric current.

Int. 20. What was common knowledge before the year 1876 concerning the employment of the energy of air vibrations to directly vary the electric current?

Ans. It has been a matter of common knowledge for twenty years that air vibrations could be made to vary electric energy, and in the device known as the Reis telephone means are employed to effect that end. Various publications in several languages give description, and some of them figures, of that apparatus, so that it may fairly be said to be a matter well known before 1876.

Int. 21. Who, so far as you know, is the inventor of the first electric telephone? And please explain fully the method practised when that telephone is used.

[*Objected to as immaterial, because this suit relates to electric* speaking *telephones.*]

Ans. If by telephone is meant a device capable of producing at a distance, by means of electricity, a sound or a succession of sounds capable of interpretation, then the common Morse telegraph may be cited as an example, for the receiver, which is called a sounder, produces a sound and follows the movements of a transmitter, which is called a telegraph key; so that the sound of the sounder reproduces in time and space the movements of the key. If, however, by "telephone" is meant a telephone capable of reproducing speech at a distance by means of electricity, then the device invented by Reis, a German, in 1860 or 1861, was the first, so far as I know, which was actually made, although others had proposed and pointed out in a more or less perfect way the conditions involved in such an attempt. In the invention of Reis there was developed a method in which the energy of air vibrations was made to vary the energy of an electric current, which electric current varied the magnetic energy of an electro-magnet, which in turn was converted into air vibrations similar in their successive changes to the successive changes in the magnetism in the electro-magnet.

This method was new at that time with Reis, I believe, so far as the actual structure of apparatus involving that method was concerned.

But that method had before been proposed by a man named Farrar, of Keene, N. H., who was not able to devise the apparatus essential for carrying it out.

[*Complainants object to all the statements of the witness concerning alleged works and alleged thoughts of Reis and Farrar, inasmuch as it does not appear that the witness has any personal knowledge on the subject, and inasmuch as he has not referred to any publications before* 1876, *setting forth anything on the subject; and further objects to any reference to the person referred to as Farrar, because no such person is named or set up in the answer.*]

Int. 22. Please compare the Reis method with the Bell method, in which the energy of the air vibrations is utilized, stating the practical difficulties incident to the use of the former method, and stating how they are overcome by the Bell method, and also explaining as far as may be necessary the scientific laws involved.

[*Same objection.*]

Ans. In the Reis method the air vibrations so act that their energy serves to vary the resistance in an electric circuit which has in it the instrument called the receiver, and as the strength of an electric current traversing a circuit depends upon the resistance in the whole of that circuit, the greater the distance between the transmitter and the receiver the less will be the current strength, and consequently the less will be the energy which can effect the receiving magnet. This is in accordance with what is familiarly known as Ohm's law, and, therefore, on that ground the efficiency of that method is very limited, while in the Bell method the air vibrations so act as to vary magnetic energy, which condition makes it possible at once to employ currents of electricity whose variations in strength may very greatly exceed those that are possible in the Reis method, and hence with the Bell method the distance to which it is possible to transmit speech exceeds anything possible with the Reis method.

[*Complainants renew the same objection, and further objects that the answer assumes Mr. Bell's "method" to be something entirely different from that which is stated and claimed in his patent, and particularly in the fifth claim.*]

[*Noon recess.*]

Int. 23. Do you regard the Bell method as the first in which the energy of air vibrations was transformed into magnetic energy? If not, what was the older method?

[*Last clause of the foregoing objection repeated.*]

Ans. I do not regard the Bell method as described, as being the first to transform the energy of air vibrations into magnetic energy. The same thing had before been done by Dr. Wright of Edinburgh, I believe.

Int. 24. Please explain the Wright method just referred to by you; but state first in what publications it is described.

Ans. The method to which I alluded is given in a book upon electricity by R. M. Ferguson, published in London and Edinburgh in 1867, pages 257 259.

The method employed by Dr. Wright was the utilization of sound-waves to vary magnetic strength, the said varying magnetic strength being converted into corresponding electric energy, such electric energy afterwards being converted into air vibrations. The electric energy, which was originated by the varying magnetic energy, possessed the property, which was well known, of effecting what is called a disruptive discharge in air, and as every such disruptive discharge in air is accompanied by sound, it follows that a rapid succession of such discharges will produce a continuous sound, the pitch of which will depend upon the number of discharges per second. In order to produce such a discharge, it is essential that the electricity shall have a very high electro-motive force, and that there shall be the possibility of such accumulation at the terminal of a conductor as to permit accumulation instead of conduction, as in an ordinary conductor. The electricity that is to do this kind of work must therefore be different in character from that ordinarily provided for electric conduction, and is particularly well adapted to accomplish that end when it originates from a succession of magnetic changes as is found in Wright's method.

[*Answer objected to unless the books referred to are produced, and the same, or copies of the passages referred to, put in evidence.*]

Int. 25. Please explain the substantial differences between this method of Dr. Wright and the method of Prof. Bell.

Ans. In the method of Prof. Bell the energy of air vibrations is converted into the energy of magnetic variations, which, in turn, is again converted into electric energy of varying strength, which electric energy is transferred and transformed into varying magnetic energy, which is again transformed into air vibrations, the latter of which conform, in all respects, to the successive changes in strength of the magnet.

In Dr. Wright's method, the energy of air vibrations causes variations of magnetic energy, which, in turn, gives rise to electric energy possessing extremely high electro-motive force, and which electric energy is employed to produce sound in air by electric dischage.

The electric discharges, however, as they occur, being the result of electric accumulation at the receiver, therefore do not correspond with the variations of electric energy which produce them. For this reason, with the Bell method, it is possible to transmit speech; while, with the other, it is impracticable.

[*Same objection as to Int.* 22.]

Int. 26. Where the sound is produced by electric accumulation and discharge, as in the Wright method, what, if anything, is there in the sound produced to represent the minuter variations in the energy of the air vibrations acting upon the transmitter?

Ans. As the discharge can only occur when the difference of potentials between the acting parts has arisen to a certain height, it follows that all the variations, small and large, will only accumulate their energy upon the receiver until enough energy with sufficient potential has been accumulated as is necessary for a discharge under such conditions. The minuter variations of energy will, in this case, not appear in the produced sounds. It is, therefore, not adapted to the transmission of speech; while in the Bell method the conditions are admirably well adapted to that end.

[*Same objection.*]

Int. 27. What method is now in common use?

Ans. The Bell method is in common use.

Int. 28. Please describe your method.

Ans. My method is the conversion of the energy of air vibrations into corresponding magnetic variations, and those magnetic variations into corresponding electric variations of high electromotive force, and the transformation of that electric energy into sound vibrations corresponding in all their consecutive changes with the changes in the high electric potential which produces them.

Int. 29. To whom are you indebted for any of the steps of your method?

Ans. For the step in my method for utilizing the energy of air vibrations for varying an electric current in order to vary magnetic strength, I am indebted to Reis; and for the means to convert magnetic changes into corresponding electric changes, to a considerable number of physicists, — Faraday, Henry, Ruhmkorf, Ritchie and others, — who showed the proper conditions for obtaining electricity of high potential by means of magnetic changes. Beyond that I am not indebted to any.

Int. 30. Why did you omit Dr. Wright in your last answer?

Ans. Because he in his devices employed a part of Reis's method, with well-known other devices, the principles in which were not invented or discovered by Dr. Wright. If, however, indebtedness means that I employ similar devices to those of Dr. Wright, subsequent to him, then I am indebted to Dr. Wright, because he combined the Reis transmitter with an induction coil before I did.

Int. 31. Please state what had been done, if anything, and what was known as to the use of variations of electric potential for any practical purpose before your discovery of your method?

Ans. I am not aware that the variations of electric potential were directly employed for any practical purpose other than in electrical measurements and in laboratory experiments before my discovery that they might be utilized for the transmission of speech, to which they are well adapted when utilized as in my apparatus.

Int. 32. What is the term "electricity" commonly used to signify among practical men, and what is its real signification?

Ans. Since the invention of the electric telegraph electricity has acquired a commercial value and the most of the uses to which it has been put have been such as require what is commonly called a current of electricity, an electric condition which requires an unbroken conductor or series of conductors to maintain, and it has hence come about that electricity and an electric current have practically come to mean the same thing; so much so that until within two or three years it was considered to be essential for electric working that there should be a closed series of conductors which constituted what was called an electric circuit. In such a circuit compound chemical substances could be decomposed; electro-magnets could be made; electric arcs for illumination could be made; a furnace might be heated; and various other physical changes could be produced, all having a commercial value, and it was denied by many that any useful effect could be produced in a broken circuit. It was known, however, that if in such a circuit as I describe a very large condenser was placed, that intermittent currents could be utilized for transmitting telegraphic signals.

[*Adjourned.*]

BOSTON, May 7, 1883.

In this case the action of the condenser is to generate by induction another current, either to overcome certain objectionable electrical conditions or to be used to operate by means of such current some device requiring a current, — as, for instance, a Morse sounder or relay. In each case it is the *current of electricity* as distinguished from *static electricity* which is sought to be employed, and for which means are provided for securing that end.

The practical differences between a current of electricity and static electricity, supposed to render one capable of utilization and the other not, were thought to be in the great energy involved in the current manifestation as compared with that involved in static manifestation. It had been shown that the current from a galvanic cell for so short a time as one second was thousands of times greater, —

that is, would do thousands of times more work than a static discharge from a Leyden jar would do. It was therefore concluded that such trifling energy as was possessed by a relatively small static charge might be considered as a vanishing quantity so far as utility was concerned. It is well known that before the art of telegraphing by the electro-magnetic method was invented a method of telegraphing had been proposed by various persons, in which static electricity was by attraction or repulsion to move a body, as was done by Le Sage of Geneva, a hundred years ago, who adopted as a means for carrying out that method a series of conductors, consisting of as many as there were letters of the alphabet. Each wire at the receiving end was provided with a pair of pith balls, which, when electrified, would diverge from each other and thus produce a visible signal at that end of that wire, which effect would be produced as often as a static charge was received on the other end of the wire from an operator provided with a suitable electric generator which could be touched to either of the wires.

The practical difficulties encountered in the attempt to carry out that method necessitated its abandonment, and the possibilities of the electro-magnetic method directed attention towards itself, and all idea of making the attractive property of electricity useful seems to have been abandoned. The names *static* and *dynamic*, when applied to electricity, were adopted to indicate the distinctions between *charges* and *currents*, so that in the end static was practically lost sight of except for lecture experiments, such as with pith balls, and the conditions necessary for currents of electricity came to be considered as the sole conditions for rendering it efficient. So entirely had this idea become fixed that when I discovered by experiment that a circuit was not essential and that speech might be transmitted in a broken circuit, electricians and physicists were at first incredulous and never failed to express surprise.

Practically, therefore, *electricity* had become to be nearly synonymous with *an electric current*, whereas really electricity is a physical condition of matter which manifests itself in two ways, — first, by attraction, and second, by being propagated with great velocity in such bodies as are called conductors of electricity. Electricity, when traversing a conductor, may be properly called a current of electricity.

In order to have a current of electricity, therefore, there must be provided not alone a source of electricity, but a conductor of electricity, a non-conductor rendering such current impossible.

[*Noon recess.*]

A distinction, then, must be made between what electricity will do and what a *current* of electricity will do. And, to make this clearer, I will hastily describe the conditions for both.

Electricity is produced whenever two physically different substances are brought in contact with each other. It makes no difference what the two different substances may be which are made to touch, except in the amount of electricity developed. In all cases the points of contact become electrified, — those on one body becoming positive and those on the other negative, — and if the two bodies so touching are conductors the electrical condition set up at the points of contact will be rapidly distributed throughout the substances, so that by appropriate tests one will be found positively electrified and the other negatively electrified throughout.

What such electrical conditions will result in will now depend upon other physical conditions present.

First. Suppose the two bodies after contact should be separated from each other, they would then mutually attract each other, and would tend to come together. This is called electrical attraction. This attraction is due to the difference of electric potentials between the bodies when *no* conductor is provided between them.

If, *secondly*, a wire should be stretched between the bodies there would be a discharge through it of electricity from the body possessing the higher electric potential to the other body. This discharge constitutes in a wire a current of electricity. This current of electricity is the result of the difference of electric potentials between the two bodies when a conductor *is* provided between them.

These two effects, *attraction* and *current*, are complementary to each other in this sense, that the energy of the current is the transformed energy of the attraction.

[*Adjourned.*]

BOSTON, May 8, 1883.

[*Present: Counsel as before.*]

Int. 33. Please describe in detail your method, and compare the method and apparatus of Bell with your method and apparatus as to substantial likenesses and differences; giving your reasons for any opinions you may express.

Ans. My method consists in utilizing the energy of air vibrations to vary magnetic energy, the function of which varying magnetic energy is to generate electricity of such high potential as to be adapted to the production of air vibrations. To effect this, or in other words, to carry out my method, I employ at the outset a device such as was first invented by Philip Reis for employing the energy of sound vibrations to control an electric current, which, in turn, acts upon an electro-magnet to vary its strength. This electro-magnet is provided with what is known as a secondary coil of wire, making of it the instrument commonly known as an induction coil. The varying strength of the electro-magnet, which is controlled by the electric current, sets up in the secondary coil a certain electrical condition which is known as a difference of potential at the terminals of the coil. That is to say, there is an electro-motive force developed between the ends of the wire constituting the secondary coil. The difference of potential so set up depends upon several conditions.

First. The change in strength of the magnet.

Second. The number of turns of wire in the secondary coil.

Third. The distance of each of those coils from the magnet which affects them.

It is roughly true that, other things being equal, the electro-motive force developed will be proportional to the number of coils of the secondary wire. So in my method it is essential that high electro-motive force should be provided. I provide a correspondingly large number of convolutions in the secondary wire. In order the better to understand the operation of my method as distinguished from the Bell method, it will be best that I should state quite fully the electrical conditions which may result from the employment of induction coils of different dimensions, and also the differences when the same coil is used under different conditions.

Suppose, then, an induction coil be considered, first, with its two terminals short and free in air. When a current of electricity is suddenly made to act upon the magnet included in the primary circuit, the action of the magnet is such as to electrify these two terminals of the secondary, one of which will be positively, and the other negatively electrified. This will be the case with every coil of every size.

This difference of electrification existing between these two terminals of wire in air is commonly known as the electro-motive force, or the difference of potential; because one of these is at a higher potential than that at the other end, it follows from what has before been said that the two terminals will attract each other, and the strength of the attraction will depend upon the difference of potential between them. If, now, instead of supposing the wires to be free in air, a conducting wire of short length, say one foot, be connected to them, the electro-motive force between the terminals of the coil will give rise to a current of electricity through it from the positive to the negative wire. If the wire be short, as supposed, and the convolutions are very great in number, the relative resistances of the wires forming the coil on the one hand and the external connector on the other, will, according to the known laws of electricity, cause the discharge between those terminals to take place almost altogether, through the short external connector; but as in every electric circuit where there is a difference of potentials between different parts and two conductors are provided, the amount that is discharged through each part will be inversely as its resistance. Thus, if the secondary wire has a resistance of one thousand ohms and the external wire has a resistance of one ohm, there will be a thousand times more go through the one ohm than will go through the coil, but the discharge will take place through both conductors, and neutralization will be effected.

If, now, instead of so short an external conductor, a conductor was provided whose resistance was very great, — say as great or greater than that of the resistance in the coil, — then the amount which will be discharged through the latter will be proportionally greater.

Suppose the external resistance infinitely great, as it will be if the terminals are in free air, and, say, a yard apart, then three distinct conditions will be the result.

First. The terminals will be electrified, as before stated.

Second. The terminals will attract each other.

Third. The electrified terminals will so act upon the air, or whatever gas the terminals are immersed in, as to propel the molecules which come in contact with such charged terminals with great velocity from them, as is exhibited in the phenomena of some of Crooke's tubes.

[*Noon recess.*]

I may then employ a coil to produce four different effects :—

First. To produce simply electrification.

Second. To produce attraction.

Third. To produce molecular propulsion.

Fourth. To produce a current.

And for each of these effects it is essential that the coil used be adapted to the end in view.

A coil best adapted to one of these may be very ill adapted to another of these effects. The coil must conform to the external conditions. Suppose, then, the end to be attained with a coil be the attracting property of a charged body. Inasmuch as the strength of attraction will depend upon the difference of potential between the terminals, their distance apart and their size, as well as upon the fact that the attracting bodies must not touch each other or be connected in any way by a conductor between them, it follows that a coil adapted to such conditions must, to produce its maximum effect, be composed of a large number of convolutions in order to the development in a high degree of difference of potential which is to result in attraction.

If the end desired be to produce a *current* of electricity in a coil of wire for the sake of making a magnet, then, for maximum effect, the secondary coil should have the same resistance as is in the external circuit, namely, the magnet coil.

If the end be to produce a disruptive discharge in air, such as is exhibited by induction coils made for that specific purpose, still other changes have to be employed to yield the required electrical conditions.

Suppose a coil to have its external wires, each a foot long, to be brought within a tenth of an inch of each other, and it be desired to produce a disruptive discharge between them, that is, that an electric spark should pass between those terminals. In order that this should be done in any degree, it is absolutely necessary that there should be a certain minimum electro-motive force. Anything less than this will not produce that result at all, although any less electro-motive force would electrify the terminals as in any other case.

It is not a matter of degree at all below the minimum electromotive force necessary, and therefore if the source of energy in the primary circuit of the induction coil was not sufficient to produce such jumping spark or discharge in air with the number of coils at first wound upon the secondary, the secondary must be enlarged by the addition of more coils, not to produce a result in a greater degree than before, but to produce a result which could not be produced at all before. It is here not a matter of degree, but of kind.

Suppose that the terminals of the coil instead of being separated a short distance should be made to touch each other: now, whenever an electro-motive force is set up in the coil, a current would traverse the wire, the strength of which would depend upon the relation of the resistance of the wire and of the coil, and this would be in any case merely a matter of degree. A small electro-motive force would yield a small current, and a higher electro-motive force a stronger current, a condition of things very unlike the former; different laws belong to each series of conditions.

It is in accordance with the known laws of electricity that if we take a wire, the two ends of which are at different electric potentials, a current will travel from the higher to the lower potential. If we take two adjacent points in such conductor, and determine the difference of potential between such points, such differences of potential are less the nearer the points taken are to each other; so that if in such wire the points taken were, say, the one hundredth of an inch apart, the difference of potential between them would be so minute that it is doubtful if the most delicate means we could employ to detect it would be able to do so; whereas, if such wire should be cut in two, and the ends brought to within one one-hundredth of an inch, the difference of potential between them would be exceedingly great, and might rise to two thousand or more electro-motive force units before any discharge could take place between them.

As there is no difficulty in measuring an electro-motive force as small as one one-hundredth of such unit, it follows that the difference in electric potential between the two points in the unbroken wire and the terminals separated at the same distance would be numerically equal to two thousand times one hundred, or two hundred thousand, which shows the enormous difference there is between a continuous circuit and a broken circuit.

It is evident, without argument, that the electric conditions requisite for utilizing one of these conditions cannot be the same as those for utilizing the other condition.

In my method I employ the conditions as are present in the example of the broken wire. My receiver consists of two plates of metal, which are really only the expanded ends of the separated terminals.

[*Adjourned.*]

BOSTON, May 10, 1883.

I will therefore explain more fully the electrical relations present in coil, transferrer and receiver. Because the terminals are separate from each other no current can pass, for the resistance is practically infinite. This condition changes the electric relations throughout; for the electric potential at the terminal of the coil can now rise to its maximum, and will thus raise the potential of that whole part of the transferrer, including the expanded terminal. That is to say, the electric potential of the whole transferrer, with its terminal, will be the same as that at the end of the induction coil wire; and similar conditions will obtain at the other end, excepting that when one of these is plus, the other will be minus. The electro-motive force in any electric source, whether from an induction coil or from a battery, is always at its maximum when the external resistance is infinite, and it steadily falls with the decrease of resistance.

For that reason it is possible to develop in an induction coil with separated terminals an electro-motive force very much greater than is possible to develop with the same coil when a continuous conducting circuit is made to connect the terminals. For these reasons any diagrams representing the electric condition of my coil, transferrer and receiver must be extremely different from those which represent any circuit of continuous conductors. If, therefore, a diagram be made in which a straight line be drawn and ordinates drawn from it at its ends to represent difference of potential between its two ends, plus potentials being drawn above the line and minus potentials below, — if this line represents a wire of uniform structure, — a line connecting the ordinate ends will represent correctly the fall of potential upon that wire. Choosing two points adjacent to each other in the wire, say the one hundredth of an inch apart, and drawing ordinates from them to the connecting line, it will be seen that the difference of potentials between those two points is very slight indeed.

Suppose, however, that the end of the wire or conductor be such as I have explained as constituting one terminal in my receiver, or in any case where the resistance is similarly infinite, the ordinates drawn from a line to represent the difference of potential upon that line will all be of the same length, and that length the same as that at the end of the induction coil, and that end will be higher than it could possibly be if a conducting circuit was employed to connect the two terminals.

So that, when we compare electro-motive forces in an induction coil in a closed and in a broken circuit, it is always higher in the broken circuit. If we compare the coil with its ends connected by a continuous conductor with a coil having its ends connected to a broken conductor, the electro-motive force present in the latter is found not to fall as it does fall in the closed circuit, and therefore the electric conditions throughout coils and conductors are not only radically different from each other, but they are so different that they are not comparable with each other, except for efficiency in the radically different work which each may be employed to do.

Let there be an electric combination consisting of any suitable transmitter competent to affect an induction coil in the ordinary way, and let there be included in the secondary connections one of my receivers. Upon varying the strength of the magnet, either to make it stronger or weaker, the electro-motive force generated in the secondary of the induction coil will immediately be transmitted to the terminals of my receiver, where attraction will result as the effect of opposing electro-motive forces when conduction cannot take place, and if movement be possible so that one terminal may move towards the other, such movement will take place, and not only that, but the electrification which resulted in such movement having done its work, having been transformed, is thereby annihilated.

Upon again varying the strength of the magnet, either by increase or decrease, the same results will follow, the electro-motive force developed being its maximum and substantially the same in quantity at the terminals in the receiver as at the terminals of the coil itself; motion of the terminals resulting, the energy of the electricity is expended upon them and therefore ceases to exist as electric energy, having been completely and directly converted into mechanical motion, which, as has been before stated, is one of the forms of energy into which electricity may be transformed. The steps in this case are these: mechanical energy, magnetic energy, electric energy, mechanical energy.

In a similar way I will consider the case when, instead of disjoined terminals, as in my receiver, a continuous circuit with the secondary of the induction coil is made, as in the Bell method. Here, on account of the continuous metallic circuit provided, any change of magnetism in the core of the induction coil will give origin to an electro-motive force, the difference of potentials depending upon the resistance in the transferrer, and in the coil of the receiving magnet, but it can never attain its maximum amount, for that is possible only on conditions which are not present. The electro-motive force of such difference of potential as is developed will now have its greatest difference at the terminals of the induction coil instead of within the receiver, and a current of electricity will flow through the whole circuit, including the receiving magnet coil, and such current within the coil reacts upon the magnet to change its strength. The variations of magnetism here depend altogether upon the amount of electricity that flows through it per unit interval of time, and the fall of potential between the two terminals of the coil of the receiving magnet may be graphically represented by a line and ordinates, as before explained. Such receiving magnet being provided with an appropriate armature, the latter is attracted with greater or less force by the magnet, and being capable of slight motion, moves in response to the solicitation of the magnet. The steps in this case are: mechanical motion, magnetism, electricity, magnetism, mechanical motion.

The two methods may then be contrasted. The end in both methods is to transmit speech by means of electricity. Each employs a series of physical conditions to attain that end. The initiatory step in each is the formation of air vibrations which constitute what we call speech. Each employs the energy of such air vibrations to control the strength of a magnet, employing substantially the same means as had before been employed by Reis and by Wright.

Beyond this, both method and apparatus are unlike.

Bell employs the varying magnetic energy to generate a current of electricity which is to actuate another magnet, which by transformation of its varying degrees of strength enables the armature to move synchronously with such magnetic changes, and thus may give out to the air vibrations similar in their successive changes to the successive changes in strength of the inducing magnet.

When this series of changes which constitute the Bell method is sufficiently complete, speech is reproduced.

In my method, the changing magnetic states at the transmitter are made to assume a different function, — altogether different from those employed in the Bell method.

The electro-motive force produced is made to be the maximum which the coil can produce and which the external conditions physsically necessitate, whether employed for any useful purpose or not. This high electro-motive force is afterwards transferred and transformed, not through the agency of a current and magnetic changes, as in the Bell method, but directly into mechanical motion, and that into air vibrations corresponding in their successive changes to the successive changes in the difference of potentials of the terminals.

[*Adjourned.*]

BOSTON, May 11, 1883.

What I mean to say is that these two methods are radically different. The kind of electrical energy employed in my method is absolutely different in kind from that electric energy used in the Bell method. All the various steps employed in the Bell method were well known and had been for a long time before 1876. I mean by this that there are no two consecutive steps involving transformations of energy for useful purposes but what were well known, and each of those steps in one way or another had been so used; whereas in my method it is true that it was not known that such electric energy could be used for any useful purpose until my discovery, and the reduction of it to the purpose of the transmission of speech.

[*Complainants object to the persistent attempt in this answer to pick out the word "method" from the claim of Mr. Bell's patent which the Court is to construe, and to assume for it and attribute to it a narrow, limited and restricted meaning, and object to the whole answer as immaterial because based upon such attributed and assumed meaning.*]

Int. 34. The objection just put upon the record reminds me to ask you whether you had any regard whatever to the phraseology of Bell's patent of 1876, or only to the substance, to find out what the method described was, and also whether you consciously limit in any way the meaning of the term "method."

Ans. In all of my answers I have used the word "method" in its ordinary sense as I understand it, and I have not intentionally limited the meaning of the word to anything less than its ordinary meaning. I have used it to express a series of steps or acts. I do not see how I can describe a series of physical conditions, standing in direct relation to each other, as do the various steps involved in the electrical transmission of speech, by a better word than the word "method," and if there are various series of steps involving different factors, different principles, different modes of action, different laws, I can do no better than to employ the word "methods" to express such real distinctions. I have paid no attention to the particular phraseology of the Bell patent of 1876, and have only tried to ascertain and describe what I found there in substance.

[*Complainants object to any testimony concerning the method referred to in the claim of Mr. Bell's patent and the invention therein set forth from the witness, who testifies that he has paid no particular attention to the phraseology of the patent.*]

Int. 35. To go from the abstract method to the concrete method, so to speak, if you find a telephone in use, and on examination find that the energy of the air-waves produced by the speaker is transformed into magnetic energy, that into electric energy, that into magnetic energy, and that into the energy of air-waves near enough like the energy of the first set of air-waves to cause the hearer to receive the same impressions that he would have received had he been within ear shot of the speaker, what *method* would you say was practised in the use of that telephone?

[*Same objection as to answer* 33.]

Ans. Such a series of changes is what is the substance of Bell's method as I understand it.

Int. 36. Now suppose that you found the electric energy utilized to be of a radically different sort from any utilized in what you have called Bell's method, and that it was in its nature unfit for transformation into magnetic energy, and was not in fact transformed in whole or in part into magnetic energy, but was utilized to set up the second set of air vibrations in a way wholly unknown theretofore, and state whether you are able to perceive how that can fairly be called substantially the same method; or whether you see any reason to doubt that it is a radically different method wholly unlike the first in every substantial respect except only as to the initial step.

[*Objected to as leading and as presenting a state of facts not existing in the case, and therefore immaterial.*]

Ans. I should say that a telephone acting by a different set of electrical conditions as described, such conditions involving discovery of themselves and necessitating invention to make useful, could properly be described as a new method. If, for example, electricity be employed to produce a light by means of the incandescence of a wire or other conductor through which a current of electricity flows, I should call that a method of lighting by means of electricity. If now it be discovered that by separating the conductors, an electric arc, so called, may be formed, and that such arc is capable of giving a more intense light than was possible before, I should call that a new method of electric lighting, although in this case the differences in electric conditions employed are not so great as they are in these two cases supposed in the questions, because in the electric lighting by both methods a current of electricity is employed and is the essential condition. They differ chiefly in the physical conditions for utilizing a current.

Int. 37. To pursue this matter one step further, please imagine now that you found a telephone in use, and on examination ascertained that the energy of air vibrations was transformed into magnetic energy, that into electric energy, that into magnetic energy which set up a second set of air vibrations like the first, but also found that the means used to effect the several transformations were each and all radically unlike any now known, would you then consider the method employed substantially the same or substantially different from what you have called Bell's method? You observe I don't ask anything relating to infringement of any patent.

[*Same objection.*]

Ans. When the succession of steps is the same and the only differences are those of the apparatus and mechanical conveniences for utilizing such steps, I should say the method was the same, whatever particular mechanical substitutes, whether known or unknown, are employed.

Int. 38. To take another illustration. Bells '76 patent, so far as concerns Fig. 7 and the description relating to it, and the method practised when that apparatus is used, shows but one means of transforming the energy of air-waves into magnetic energy, and that is by transforming the mechanical energy of air-waves into another sort of mechanical energy, — the vibration of the armature of the electro-magnet, — and that mechanical energy into magnetic energy. But in a large majority of telephones, as I understand it, the mechanical energy of air vibrations is transformed into the mechanical energy of a tympan, and that into the familiar form of electric energy and that into magnetic energy. Now have I, in your opinion, described two *methods* which are substantially different, or only an underlying method, so to speak, and an improvement on that method?

[*Objected to as leading and as assuming a limited meaning for the word "method" different from that expressly given to it in the patent referred to in the question.*]

Ans. With the exception as to the relation of the mechanical energy of a tympan as being converted into electric energy and substituting for that, that such mechanical energy of tympan is employed to properly control a current of electricity, I should say that the two ways described are substantially the same; one of them may be an improvement upon the other, but it is not a departure from the plan of the other.

Int. 39. To return now to the question of substantial difference between the electric energy utilized in your method and that utilized in Bell's method, please consider the two from various points of view, as for instance, the mathematics involved in the one and in the other, the electric units active in the one and in the other, the means for determining the electric energy efficient in the one and in the other, and the state of knowledge as to one and as to the other, and any other points of view which you believe throw a practical light upon the substantial differences between the two.

[*Same objection to the use of the word "method" as heretofore stated.*]

Ans. The energy which a body possesses, no matter how derived, is one thing; how that energy may be used and how it may be transformed, and how it may be measured, are very different problems. It is common to measure electrical energy by providing for it a conductor through which it may flow as a current of electricity; for instance, a galvanometer is an instrument that measures the quantity of electricity that flows through its coils per second; a current of electricity is, therefore, what the galvanometer is competent to measure, and any electricity to be measured by it must necessarily be made to assume the current form of electricity.

[*Noon recess.*]

An electrometer, on the other hand, is an instrument for measuring a static charge. One of these instruments cannot be substituted for the other for purposes of measurment; that is to say, an electrometer cannot measure a current, and a galvanometer can only measure a current. This is because the two ways in which electricity may act are so radically different from each other. The energy of an electric current or the work which it is capable of doing is numerically equal to the product of the current into the electro-motive force into the time it acts; thus, let C equal current and E electro-motive force and T time in seconds, then $C \times E \times T = W$, where W represents the work that such electric current will do in time T; and as a magnet telephone receiver does not differ from a galvanometer in its electric relations, it follows that the above expression is applicable to it as well as to a galvanometer; indeed, such a telephone receiver has been frequently employed for the detection and measurement of electric currents.

With the electrometer the laws involved in the measurement of static charges are highly complex, with many factors. The strength of attraction between two oppositely electrified surfaces depends upon the difference of potentials, the size of the plates, their distance apart; and these not in simple proportions, but in the ratio of their squares or some other multiple, and introducing units and constants which are not to be found in the measurement of currents.

The units employed in the measurement of currents are for electro-motive force volts; for resistance, ohms; for currents, ampéres; for time, seconds. A unit current for a unit of time is called a coulomb.

A static unit is called a farad, while the attractive effect of a charged body has no name, because its importance has heretofore not seemed to require it.

In the two methods I have described, the electrical units required and utilized are current strength in coulombs in the Bell method and farads in my method.

[*Adjourned.*]

BOSTON, May 12, 1883.

Mathematically, then, the efficiency of the electricity in the Bell method is E C, while the electricity available as attraction in my method is expressed by $\frac{E^2 S}{8 \pi D^2}$ in which E is electro-motive force in volts, S the surface of plates, D distance between plates and π the ratio of the diameter of a circle to its circumference. The above expression gives the force of attraction between two electrified plates, such as constitute what is known as the attracted disk electrometer, which is substantially like the conditions in my receiver. As statical electricity has not had any commercial value, it has not been the subject of such investigation as to the relation of its energy as has been the case with currents of electricity, but the above expressions, which are well known, serve to show the radical difference between the two forms. It is seen that the only common factor is the difference of potentials or the electro-motive force E. Beyond that they are not simply unlike, they have nothing whatever to do with each other. What I want in my method is variations of attraction. What is wanted in the Bell method is variations of magnetism; and each provides appropiate means to secure these ends.

Int. 40. Please state briefly how that form of energy known as electricity was utilized before you discovered your method of transmitting sounds, giving a typical illustration of the several ways known before that.

[*Same objection to the persistent misuse of the word " method."*]

Ans. Electricity has been employed in a very great many ways, and it will be sufficient for this purpose to enumerate some of the phenomena which electricity is known to be competent to produce.

1. Electricity is competent to decompose compound chemical substances, as, for instance, water; and for utilization of this property of electricity a common and simple case is the production of a blue mark by means of the decomposition of the ferrocyanide of potassium, as in Bains' chemical telegraph.

2. Electricity is competent to deposit one metal upon another metal; and such electro-deposition of metals has become a great industry.

3. Electricity is competent to produce a magnet, and out of that has grown the common electric telegraph.

4. Electricity is competent to produce heat, the highest temperature which man is able to produce at present, being that in an electric arc, and is used for the fusion of refractory substances, such as platinum, gold, steel, etc.

5. Electricity is competent to produce light, and the two rival methods of lighting, namely, that by the electric arc and that by

incandescence, are simply developments of the possibilities of electricity in that direction.

6. Electricity is competent to reduce friction between bodies, and is utilized for this purpose in one of Edison's telegraphs and in his motophone.

7. Electricity is competent to produce various physiological effects, and is used by some physicians as a therapeutic agent.

8. Electricity is competent to give a torsional strain to a conductor through which it flows, either right handed or left handed, according as the direction of the current is toward or from the observer. This has been utilized to measure the strength of the current flowing through the wire, as a kind of galvanometer.

9. Electricity is competent to produce very various gaseous phenomena, and a motion by impact of projected mólecules upon the paddles of small wheels, as is exhibited in various forms of Crooke's tubes.

10. Electricity is competent to affect a magnet, and will set such magnet at right angles to the wire through which it flows, provided the magnet is free to move and the current be strong enough. Galvanometers are constructed utilizing this action of electricity.

11. Electricity is competent to twist a ray of light, either in air or other transparent medium; but this is only used at present, as for as I know, in the study of physical phenomena among molecules.

12. Electricity is competent to produce in the non-material substance called ether a certain condition which is generally known as the electric field, — a field within which various interesting phenomena are manifest, and which is at present a subject of investigation by physicists.

13. Electricity is competent to produce either heat or cold at a junction of metals, according as the current flows this way or that, as in what is known as Peltier's phenomenon.

14. Electricity is competent to produce a noise by disruptive discharge, as in the phenomena of thunder storms, and on a small scale by electrical machines.

15. Electricity is competent to produce attraction. But this latter phenomenon — which has been known for a very long time, perhaps was the first observed electrical phenomenon of any experi-

mental kind — has not had any commercial development, so far as I know, until my discovery of its adaptability to the transmission of speech.

In all these cases which I have enumerated, excepting cases 12 and 15, the electric energy has been that which is involved in an electric current as distinguished from statical electricity. In every one of these cases the resulting phenomenon, of whatever kind, is due to the transformation of the electricity into some other form of energy. For example, when electricity is said to produce heat, the electricity is transformed into heat,— it ceases to exist as electricity. When the transformation is complete, there is no residuum; the electricity is annihilated, and the energy as it now exists is vibratory, molecular motion or heat. The same may be said of each and every one; but this is only stating in this particular way what is commonly called the law of the conservation of energy.

Int. 41. Now as to the practical use of what are called secondary coils. Please explain and illustrate briefly how such coils were used before your discovery, and how in your method.

Ans. Induction coils are capable of developing three different physical conditions, according to the arrangement of their external connections.

First. A current through an external unbroken conductor.

Second. Disruptive discharge when a break in such external conductor permits, which depends upon the distance apart of the broken terminals.

Third. The development of an electric field without current or discharge when the terminals are too far separated for disruptive discharge. In this case there is no electric current whatever between the terminals, — no electricity whatever passes from one to the other external to the coil, — and electrically the conditions are radically unlike the cases when a discharge can occur either through the continuous circuit or by a disruptive discharge, which is a transient current. The electric work is done upon what is called the electric field, as alluded to in No. 12, as recited in my last answer.

[*Noon recess.*]

Induction coils have been employed for the transient currents which they can set up in a conductor and for disruptive discharges in physical experiments, and for the latter purpose some immense coils have been constructed with which a spark in air more than a yard long could be produced. But even in this case I do not know that such disruptive currents have been utilized for any business purpose whatever. So that, practically, the only such use to which induction coils have been put has been for the production of currents in a continuous circuit within which is included the instrument or apparatus for utilizing it. And as it was found, practically, that for such economical use small coils were better adapted than large coils, on account of the relation of resistance to current strength, there has, therefore, been neither demand for nor knowledge of the possibility of utilizing such high electro-motive force as is necessary to effect my purpose until I discovered the present method of utilizing it.

Before that time induction coils for any practical purpose as distinguished from experimental purpose had been constructed with small resistance and capable of developing relatively low electro-motive force.

In my method I want as high an electro-motive force as I can get, the higher the better. I therefore make my coils with very much greater resistance by increasing the number of turns in the secondary wire; and my most efficient coils have had a resistance twenty times greater than those in common use with the Bell system, or about three thousand ohms. Such high electro-motive force with such an origin is not conditioned by what is known as Ohm's law, and for that reason any external conductor may be employed between the induction coil and my receiver without regard to its resistance dimensions. What I mean is, that resistance between such induction coil and my receiver is practically of no account, for with a resistance of fifty thousand ohms, or more, the loudness and clearness of articulation in my receiver is hardly appreciably different from what it is without any resistance, while such a resistance would so diminish the loudness of the Bell receiver, whatever transmitter might be used, as to render it quite useless as a practical instrument. But this is in accordance with what has before been stated in another way, that the conditions for the successful working of these two methods are radically different, and in many cases exactly opposed to each other.

Where one wants current, the other does not.

Where one wants resistance, the other is better without.

Where one wants a large conductor, the other needs the smallest possible.

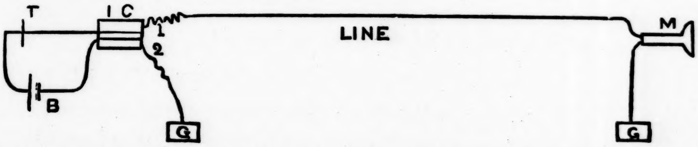
Where one wants a certain electro-motive force, the other must have many times that electro-motive force.

Where one wants an electric field, the other wants magnetism.

Where one requires a distinct mechanism for the transformation of electric energy, the other needs nothing whatever except for the convenience of handling, not for transformation.

These are some of the contrasts in the working with electricity of high electro-motive force and with a broken circuit compared with a low electro-motive force and an unbroken circuit.

Int. 42. Please look at the following diagram, copied from Fig. 1 in the affidavit of Prof. Cross,



and state whether that correctly represents the Bell electric speaking telephone as commonly used, and explain the necessary relations for practical efficiency between the resistance of the induction coil I C and the resistance of the transferrer or line and the coil which makes a part of the receiver.

Ans. This diagram correctly represents arrangements employed in the Bell system. It represents a continuous electric circuit from ground through induction coil, through line and magnet or receiver to ground. This is the best method, and, indeed, the only practicable method, of working this system; but the resistance in the induction coil must stand in a certain relation to the resistance in the line and the coil within the receiver, in order to obtain the maximum result.

Theoretically, the two coils should have the same resistance; and, practically, they do not differ to a large amount.

If the line or transferrer has an appreciable resistance, the induction coil must have an increased resistance. This is in accordance with both theory and practice.

arrangement is entirely impracticable for a receiver M depending upon current strength, and is the worst arrangement for the Bell receiver. That it would even work in that way and be heard at all was not known until after my discovery of the possibilities of a broken circuit.

In Fig. 5 is represented my line with infinite resistance including in that line both my receiver and the magnet receiver. With this and a small coil at I C, the effect in C will be very weak, as will also the effect in M. With a coil at I C sufficiently large to operate my receiver, the receiver M would also be operated to some extent; but my receiver would be provided with its proper conditions, and would work admirably, while M would have conditions which were extremely ill adapted for its work, and its performance would be relatively meagre. That M should perform at all is not due to any current from I C that operates it, but to an induced current having its *origin* at the back plate of C. There is a complete transformation of the electric energy between the plates in C and the mechanical energy of movement of one plate in C, as well as the varying states of charge upon the front plate of C give rise to an induced electrification upon the back plate of C, which electrification distributes itself, as it will in any case when conductors are provided, and will therefore go from C through M to the hand as a current of slight strength, and therefore may operate M. It is therefore not to be inferred that because M will operate so as to be heard, that it implies that a current of electricity has passed the plates in C.

In Fig. 6 there it still represented my line of infinite resistance, in which is included in what is called parallel circuits one of my receivers, C, in one, with a resistance R and a magnet receiver in the other. With this arrangement with a small coil at I C the performance of both receivers would be extremely poor; in mine because electro-motive force is insufficient, and in the magnet because current strength is feeble. With the large coil the performance of mine at C would depend upon the resistance in the other part of the circuit R. The smaller that resistance the less efficient will be my receiver. But by making R large, say 5,000 or 10,000 or 50,000 ohms, its performance would be good; and when resistance in R becomes infinite, it performs its best; while the performance of the magneto will be nothing at all.

In Fig. 7 the conditions for the performance of my receiver are such as are required when the resistance in the branch circuit R M is high. For the receiver M the conditions are unfavorable and such as would never be adopted except for experimental purposes. The arrangement is useless, practically, for it. But that M should perform so as to be heard at all, a coil I C of high electro-motive force would have to be employed: the common coil would be useless.

In Fig. 8 is a singular combination, in which my receiver C has its front plate used simply as a part of the line wire, and so does not differ materially from the line as shown in Fig. 4. Prof. Cross seems to think it necessary to state "that a current did actually flow through the plate of the Dolbear receiver." It seems strange to me that it should be necessary to remark that there will be a current of electricity flowing through a metallic conductor when its two ends are at different potentials. In this case, seeing that the front plate of C is a part of an unbroken metallic circuit from I C to R, it of course follows that any current passing in a line towards R from I C will pass through that part of the conductor in C which is included in that circuit, and any instrument beyond C, as at M, would be affected by that current. But, if it be meant to imply that because when one plate of my receiver is made a part of a metallic circuit by coupling it at two point on its edge so that it may act as a continuous conductor that a current in any proper sense of the word operates my receiver, he is mistaken. I do not think he meant to imply that, but the statement is liable to be misinterpreted and misleading.

I have shown over and over again that for the operation of my receiver it is only necessary for one of the plates to be electrified, and inasmuch as this line shows conditions appropriate for electrifying this plate, though not the best adapted to that purpose, it follows that my receiver C ought to be heard through the agency of such electrification, provided always that the electro-motive force of I C be great enough, and the resistance in R be also great.

In Fig. 9 is shown a device which it seems was intended to prove the existence of a current of electricity in the secondary helix when the ends of the helix are in the air and insulated.

This experiment seems to imply a difference in interpretation of what takes place in an induction secondary coil, and is an attempt to prove a given statement, namely, that there is a current in such coil under such conditions. Prof. Cross says, "From this I got articulate speech perfectly," which leaves the inference that he had therefore proved the existence of a proper current in an induction coil when there was no external connection except such as he had inserted in that coil. It however does not follow, that because he heard articulate speech with such a device, that therefore it was due to a current generated in that coil, for I have experimently proved in two different ways that speech may be reproduced in a telephone as at M without such connections as are here represented.

First. Let I C be an induction coil of high resistance, and let the terminals from M be simply brought into the neighborhood of such coils I C when the terminals are in free air, as shown, and an induced current is set up in the coils of M sufficiently strong to reproduce speech in M when the terminals of I C are both exposed in air, as shown.

Second. With simply an unclosed circuit in M, and with the external wires in M moved out of the field as far as may be, when M is brought into proximity to the coil I C the change in the magnetism in the core I C may be sufficiently great to act inductively upon the magnet M and reproduce speech. I have repeatedly heard in this way; but in the case as shown in Fig. 9, while it does not prove the existence of the alleged currents, I am not disposed to deny them altogether, for, although when an external connection like M is made with the interior of such a coil, it changes profoundly the electrical relations within the coil, and therefore can hardly be used to demonstrate what takes place in an ordinary coil unbroken at such a place. I have before said substantially that when an electro-motive force was developed between the two ends of an induction coil what would happen would depend upon external conditions. When these two terminals of different potentials are shown free in the air, as in the Fig. 9, and no work is done upon other bodies in the neighborhood, the discharges, that is to say, their restoration to electric equilibrium, can only take place by reaction within the coil; and in a sense such reaction might be called a current or currents; but even then, such use of the term in such a place would need an explanation.

[*Noon recess.*]

In Fig. 10 the arrangements are only duplicates of the arrangements shown in Fig. 3 when C in Fig. 3 properly represents one of my receivers. When the electro-motive force in I C is high, the discharging current towards C will operate receiver M; and C will also have good conditions for performance. Within C, however, will take place that same inductive action which gives rise to an electro-motive force, which will be transmitted as a current through M to C′, when the same action will be repeated in C′, and so on. I have often coupled in such circuit a considerable number of my receivers, — as many as fifteen in such a circuit, — and articulation was distinct and loud in each.

This experiment only shows that there are currents of electricity between the receivers, but it does not show that there are currents within the receivers, or that the receivers are actuated by currents in any such sense as is true for the magnet receiver M. I wish to again reiterate that what takes place in C is not a current, but inductive action, in which one electrified plate attracts the other plate adjacent to it, giving rise, also, at the same time to an opposite electrification upon the second plate in such sense that the difference of electric potentials between those plates is made to be the maximum possible, — a condition of things that it is utterly impossible to provide when the smallest conducting medium is placed between the plates in C.

That which separates those plates is as perfect a non-conductor of electricity as we are acquainted with, namely, air; and, so long as C acts in the way of a condenser, so called, it cannot possibly act as a conductor. A conductor and a condenser are very far from being identical, and it is a misuse of terms to speak of the conductivity of a non-conductor, or to imply that a current of electricity goes through a condenser in any such sense as it goes through a conductor.

Furthermore, whenever conduction takes place, there is no electrical transformation in any sense. One electrified particle transfers to its next neighbor by contact its own electrical condition, while, where induction takes place, there is a complete transformation of the electrical energy; and this transformation may again be resolved into either the motion of an adjacent body or into an electric current in an adjacent conductor; but in the latter case there is a double transformation.

In Fig. 11 the conditions are right for the working of my method, for the resistance between the terminals is infinite; but the conditions for the working of the magnet telephone are at the minimum. With a large resistance between I C and C, the magnet telephone will be materially reduced, while such resistance may be enormously great and still be perfectly audible with mine, as at C. Prof. Cross says that he put in over 1,000,000 ohms of plumbago resistance; that this prevented utterance in my receiver. The experience of Prof. Cross in this matter is in utter discordance with my experience, and I think it to be highly probable that there was some defect in his connections; for not only have I inserted resistances equal to those employed by him and still heard perfectly, but I have quite detached my instrument from the line and separated it from it by many feet, and thus practically inserted resistance, measured not by millions but by thousands of millions of ohms, and still heard perfectly. In this case it is perfectly plain, and not to be disputed, that no current of electricity from the induction coil operated my instrument, for it was entirely disconnected, so that no current could possibly reach it.

In all of these experiments by Prof. Cross I had preceded him in the work, and I am sure that he has been led quite afield upon grounds which, however plain they may appear now, were new to him and to everybody until after my discovery of what could be done in an electric field and by means of static charges of electricity, and which line of experiments were never undertaken, even in an experimental way, until the necessities of defending a patent arose.

Int. 46. You have referred in one of your answers to the slight difference of potential between any two adjacent points in any part of a closed circuit, and to the large difference of potential between the terminals of a broken circuit. Now please consider any two adjacent points in the transferrer of Bell's method as shown in Fig. 1 of Prof. Cross's affidavit, and any two adjacent points in the transferrer in your method as shown in Fig. 2 of Prof. Cross's affidavit, and state how the potentials at such points vary from each other; and also how they vary from the potential of the terminal convolution of the coil I C. By transferrer I include the wire marked "Line" in Fig. 1 and also the wires, one leading from I C to G and the other leading from M to G.

In the course of your answer, please explain also how the potentials vary between that part of the transferrer which joins the coil of M and that part which joins that coil with G.

Ans. In Fig. 1 is represented what is called a continuous circuit from ground to ground. Any continuous source of electricity placed within that circuit will give a continuous current of electricity which might be measured by a galvanometer or any other way. Any difference of potential, therefore, that is set up in the coil I C, will be at its maximum at the points marked 1, 2, that is, the immediate terminals of the coil. Such electro-motive force provided with a continuous conductor of line through M to G will suffer a fall of potential from the point marked 1 through M to G. The *difference* of potential between any two adjacent points, suppose, for instance, in the middle of the part marked "Line," whose distance apart is small, say $\frac{1}{100}$ of an inch, would be so exceedingly small as to be immeasurable. Not that there would be no difference of potential, because, as I have said, there is a gradual fall of potential through the line to the ground, the fall of potential at any particular place depending solely upon the resistanee at that place. As the resistance between the points chosen is almost infinitesimal, it follows that the difference of potentials will be very small. In other words, the less the resistance, the less the difference of potential, which follows from the laws operating during conduction of electricity. In the instrument at M, Fig. 1, the resistance is purposely made considerable in order to avail of the current strength traversing it, and the difference of potential between the two immediate terminals of that instrument M will follow the same law as is followed in the line or in any part of such circuit, namely, that the fall of potential will be directly as the resistance between the points measured. As G and G are both in the earth, the potential of it which is zero when undisturbed will be changed, it being more or less at each place according as the current goes this way or that.

This may be roughly indicated in the following way: Suppose the difference of potentials between 1 at I C and G to be one hundred volts. With the higher potential at 1, then the discharge would take the direction through line and M to G. If the line be supposed to have practically no resistance, then the difference of potential at the entrance of the line into M and that of its emergence to G would be one hundred volts, which might be represented by a line drawn, whose length should represent the resistance of M, say one hundred ohms. If from the left end of such line a line be drawn at right angles, whose length shall be taken as one hundred volts, then a line connecting the two free ends of these two drawn lines will correctly represent the fall in potential between the ends of the wire coil in M. As G is the point of no potential, the whole fall in potential will be represented by the hypothenuse of that right-angled triangle. If, however, the line has some resistance, then the fall in potential upon it may in like manner be indicated by the difference in resistance between 1 and M, and also between M and G; such a diagram may now have drawn upon it from any two adjacent points in the line representing resistance two vertical lines drawn to meet the line representing the potential at that point. These two points may then be seen to have but the slightest difference in potentials.

In Fig. 2, which is a representation of my line, and consists only of a transferrer from I C to C, the case is wholly different.

As the plate in my receiver at C is absolutely the end of the transferring conductor, it follows that no means is provided for the discharge by conduction, and therefore such plate may acquire the same potential as exists at 1, and will do so if line have practically no static capacity. This is the condition for maximum results with my method. A diagram drawn with a line to represent the transferrer line, the length of which shall represent the static capacity of the transferrer line, and having ordinates drawn at its two ends to represent the difference of potentials at those two ends will have such ordinates the same in length, because, there being no discharge on account of lack of a conductor, the potential cannot fall in any such way. If the hand, as at C, be made to assume the relation of a ground connection to the back plate, still, as there is no discharge between them, the potential of the front plate cannot fall, and the difference of potentials between those plates will be practically equal to the difference in potential between terminal 1 of I C and the ground.

To state it in another way, the two plates in C are separated from each other by a short space, — say the one hundredth of an inch, — which prohibits conduction, and hence the passage of a current. The difference of potential therefore must be at its maximum, and, as before stated, the nearer these two plates are to each other the greater may be the difference of electric potential between them, — a condition which is exactly opposite to that condition when conduction takes place. A broken circuit in this way is strongly contrasted with a continuous circuit both in the physical relations and the work that each is competent to do.

With the line as shown in Fig. 1, where a continuous conductor is furnished as shown, it is not possible for the electro-motive force to rise to that degree to which it may rise when the external condition is as represented in Fig. 2 with broken circuit at C, because electro-motive force varies with the resistance; the greater the resistance the higher the electro-motive force.

The resistance in my line being practically infinite, the electro-motive force may attain its maximum.

[*Adjourned.*]

BOSTON, May 16, 1883.

Int. 47. Please consider now the several forms of apparatus described in the Bell patent of 1876, and state whether either of them has ever been put to any practical use, so far as you know or have heard, and also what practical value or utility either of them has, in your opinion, explaining the inherent difficulties, if any, attending the use of such apparatus and giving the reasons for all the opinions you may express.

Ans. In Fig. 5 of this patent of 1876 is shown a plan for a double-acting device in which the two parts A and I represent similar devices, and so intended to act that when motion is imparted to the part C in A that vibratory motions having a particular period on account of the fact that C is made to be a reed, such vibratory motions characteristic of the reed C, setting up in the coils and circuit corresponding electric pulsations which can, in turn, make *h* to vibrate, only provided that the vibratory rate of *h* be the same as the rate of C. The usefulness of this is simply that of a diagram which may and does illustrate certain magnetic and electric relations; but where the involved energy necessary for doing work of any sort is wellnigh at its minimum.

The device Fig. 5 when constructed as shown has, I believe, no importance whatever for any useful purpose, and has not, so far as I know, been applied to any useful purpose up to this time.

I do not know that there is any demand for any device competent to do what Fig. 5 will do that cannot better be done in other ways.

In Fig. 6 is shown a combination in continuous circuit of nine such instruments as are shown in Fig. 5, but as the relations between the motion, the magnetism and the electric current are not of an economical kind, and are interesting only theoretically, the same remark applies to Fig. 6. It represents an impracticable system, interesting in theory but with no practical use.

In Fig. 7 is also represented not a practicable instrument, but a diagramatic invention in which new relations are involved, and shows an entrance into a new field, inasmuch as sound-waves in air, such as those made by the voice, are to expend their energy in such a way as to set up magnetic variations in *b*, and through a succession of operations involving electricity and magnetism set up in the air in L vibratory motions similar to the vibratory motions set up in A. This device shows how that may be done, but the apparatus when constructed as shown is probably as inefficient for the specific purpose it was to perform as could very well be devised. So impracticable was it when constructed by its inventor that he was himself not able to make it do what it was intended to do. He said in his lecture before the Society of Telegraph Engineers in London, Oct. 31, 1877, that he was unable to hear even a faint sound from it, and that after many experiments attended by the same results. He declares that the results were "unsatisfactory and discouraging." A great deal of care and patience has been spent upon the structure of this particular device within the last three or four years in order to prove that it will do what it was declared to be invented to do, and now it may be heard to poorly reproduce speech, but it has never been and is not now a practicable instrument, and has never been made or sold as such.

I do not mean to imply that in that device there is not shown a new idea of the very highest importance, but only mean to assert that to make that idea of commercial importance as distinguished from scientific importance still further invention had to be made, and an invention of my own in 1876 was afterwards incorporated, and made it immediately the practicable instrument now known as the magneto telephone.

The inherent difficulties in Fig. 7 are of two different kinds: first, mechanical; the second, electrical. The movable armature *c d* which is attached at its lower end to *a* in A has, on account of its pendency, a rate of vibration of its own somewhat similar to that of a pendulum, and for that reason it is not so free to respond to the movements at *a* as it should be in order to faithfully follow the motions of *a*. The heavier the arm *c* the greater would be this difficulty, and therefore the relations between the movements in air in A and those in the movements of *c* cannot be synchronous as they should. What is true concerning the part *c* in A is also true for the corresponding part *h* in L, so that in general it may be said that the armatures in A and in L are not adapted for the work they are intended to perform. Electrically the magnets *b* and *f* are what are known as electro-magnets as distinguished from permanent magnets. The current of electricity in this had a double function to perform, — to maintain the magnetism of the electro-magnet, as well as by its changes to change the magnetic strength; an arrangement which has been abandoned altogether and permanent magnets have been substituted.

Either of these two reasons would be sufficient to prevent such devices as shown in Fig. 7 from having any commercial importance, while both of them render it entirely useless.

[*Answer objected to because it does not appear that the witness has any adequate knowledge or means of knowledge concerning the matters testified about, and because the parts relating to Fig.* 5 *are immaterial.*]

[*Noon recess.*]

Int. 48. What knowledge and means of knowledge have you as to the practical usefulness of the instrument shown in the Bell patent of 1876?

Ans. My means of knowledge are two, theoretical and practical.

Theoretically I am well acquainted with all the conditions involved in the transformations of energy when speech is transmitted in all of the well-known methods, and several methods not so well known. Such knowledge I have obtained, not simply from books, but by experiment in a very wide field.

My opportunities for knowing all about telephones have been as good as the best, for I have experimented with them with skilled assistants for several years, and of the four different kinds of telephones which are well known, namely, the magneto telephone, the rotophone, the static telephone, and the motophone, I myself invented three of them, the first three named.

As a skilled mechanic I speak of mechanical arrangements, having learned the machinist's trade and worked for years as a machinist, and when I have said that the device shown in the 1876 patent is practically useless, I give not only my own judgment, but that of Prof. Bell himself, who declared it to be "discouraging" and "unsatisfactory" even "after many experiments."

Int. 49. What have you done as to the Reis telephone described in the following publications [*now put in evidence*]?

"Zeitschrift des deutsch-osterreichischen Telegraphen-Verein," published at Berlin, Prussia, in the year 1862, Vol. IX., at page 125.

"Electricity," by R. M. Ferguson, published at said London, and at Edinburgh, Scotland, in the year 1867, pages 257–259.

"The Telegrapher," published in New York, N. Y., in the year 1869, Vol. V., No. 39, at page .

"The Manufacturer and Builder," published in said New York in the year 1869, Vol. I., at page 129.

"Wonders of Electricity," by J. Baile, published in said New York in the year 1872, at pages 140, 141, 142 and 143.

"Die Fortschritte der Physik," von Dr. E. Jochmann, 1861, pages 171, 173, and 1863, page 96.

"Zeitschrift of the German Austrian Telegraph Association for 1862," page 125.

"Polytechnisches Journal," von Dr. E. M. Dingler, Nos. 168, 169, Augsburg, 1863, pages 23, 185 and 399.

"Deutsche Klinik," No. 48, Berlin, Nov. 28, 1863, pages 468, 469.

"Deutsche Industrie Zeitung" for 1863, Chemnitz, No. 16, page 184, No. 18, page 208, and No. 22, page 249.

"Frankfurter Conversationsblatt," Nov. 29, 1861, and June 30, 1863.

"Polytechnisches (Physikalisches) Centralblatt," 1863, pages 857, 859.

"Polytechnisches Notizblatt," von Prof. Dr. Rud. Boettger, Frankfurt a/M., No. 6, XVIII., Jahrgang, 1863, pages 81, 84 and 225.

"Didaskalia, Blaetter fuer Geist, Gemueth und Publicitaet," Sept. 28, 1864, No. 232.

"Die Gartenlaube," Leipsic, 1863, No. 51, page 807.

"Die Neueren Apparate der Akoustik," Von Pisko, Wien, 1865.

Reis's Descriptive Circular, Frankfort a/M., 1863.

"Jahresbericht des Physikalischen Vereins," Frankfurt a/M., 1861.

And produce the instruments tested by you, and describe what work they will do, and also point out any fallacy as to the theory set forth in such of the publications above mentioned as you have read.

[*Question objected to as calling for incompetent evidence.*]

Ans. I am not acquainted with the German language, and have therefore not read in the original several of the publications alluded to in this list, but I have read several translations of the description and purpose of the Reis telephone and am tolerably familiar with what has been written about it in English. I am also familiar with the device itself in an experimental way, as I have experimented a great deal with the devices invented by Reis.

I will first describe what I have done and the results which I have obtained with the use of such apparatus. As a Reis telephone consists of two different instruments, each having a function different from that of the other, it will be convenient to take each of these separately, and first, the transmitter. The Reis transmitter as made by him consists of an air chamber, generally of a cubical form, but sometimes made quite shallow, into which sounds of various sorts in air might be produced by means of a short front tube. In the top of this air chamber a hole was cut, and over it was stretched a taut membrane, the function of which was to vibrate with a greater amplitude than was possible to the more solid parts of the box.

Upon the middle and on top of this membrane a piece of thin platinum was glued, which piece of platinum was soldered to a piece of wire connected with the more solid part of the box so as to be easily connected to a wire leading from the battery.

A V-shapped metallic piece was made of such a size as that the angle of the V should just reach the middle of the platinum upon the membrane, while the legs were supported upon the wooden part of the box. One of these legs was made to form part of an electric circuit, which had its connections with a screw cup, as is usual. At the angle of this V-shaped piece was fastened a short piece of platinum wire so that the end of the latter might touch and rest upon the platinum piece that was cemented to the membrane. When this device was coupled at its external connections with the wires from a battery, a current of electricity would flow through the provided connections, which current might be broken by lifting the platinum wire point from the platinum piece upon which it rested. Such breaking of the current by breaking the contact at that place could be effected by sound vibrations, provided they were strong enough to move sufficiently the membrane and make it to toss up the part resting upon it.

In that way a current might be broken a great many times in a second, which number must depend upon several conditions.

First. The number of vibrations performed by the membrane.

Second. The amplitude of such vibrations.

Third. The distance to which the movable V-shaped piece was thrown. As the latter piece, when once it has been raised a short distance from the membrane and so has broken the circuit, can only fall at a certain rate, which will depend upon gravitation alone, and for a short interval is a very small distance indeed, it follows that the membrane may vibrate a number of times between the times when the wire is thrown up and when it again falls so as to renew contact. This evidently can take place only in an irregular manner, which, in any case, will depend, not upon the pitch of the sound which produces it, but upon the strength of such sound, or the amplitude of vibration of the membrane. The membrane, if light, may move quite synchronously with the sound waves which actuate it, The current, therefore, in such a case, would be broken in a corresponding irregular way. If, however, the sound vibrations were not strong enough to completely separate the platinum wire from the platinum disk, but should only have its pressure due to its weight varied upon it, the current flowing through such terminals that were varying only in the amount of pressure would only be varied as to strength of current passing through those points, and there would be no disruption. There would in that case be what is now called an undulatory current passing those terminals, the undulations in which, when caused by sound vibrations actuating the membrane, would correspond precisely with the undulations in the air which produced them.

There is still another electrical condition to be cited here. Whether an electric current is broken when a break is made in the conductor will depend upon the extent of the break and upon the electro-motive force present. If the electro-motive force be considerable, there may be an entire break in solid conductors, and yet the current continue to pass.

This condition is well seen in what is called the arc light. A distinction must therefore be kept in mind between a break of *contact* and a break in *current.*

A break of *contact* does not imply a break in *current.* It may imply only an increase in resistance; from which it follows that with a high electro-motive force it would be impossible to break the current altogether between the platinum terminals in the Reis transmitter. Inasmuch then as it is theoretically possible with such a transmitter to so modify a current of electricity as that such modifications in strength will correspond with the changes present in air vibrations when speech is produced, it follows that such a device as has been described is adapted to transmit speech, provided some device is employed for the reconstruction of such electric energy into sound-waves be provided.

This instrument which I exhibit [*now put in evidence and marked, "Defendants' Exhibit Reis Transmitter, W. A. C., Spl. Ex'r"*] is such a Reis transmitter as I have described, and does not differ in any respect from those made by Reis himself. With this instrument used as transmitter I have repeatedly heard whole sentences of spoken words, thus proving that the instrument is competent to produce such changes in an electric current as are competent to transmit speech, whether such changes be called vibratory, undulatory or intermittent. The name applied may be more or less appropriate, but that has nothing to do with what actually takes place, for the latter may be tested by appropriate means without any attempt at description of what takes place.

Secondly, as to receivers. In Reis's experiments he adopted a device invented by Dr. Page, for the production of sounds, in which a varying current of electricity passing through the coils of an electro-magnet varied the magnetic energy of the core of the magnet; such change in magnetization being accompanied by a change in the dimensions of the core, which change results in the production of sound. As the current through the coil is a continuous one, so long as there is no break elsewhere in the current and as any change in current strength affects in the stated way the electro-magnet, it follows that such device is competent to transform electric energy into magnetic energy and the magnetic energy into sound vibrations corresponding in all their successive changes to the successive changes of the magnet producing them. In other words, the Reis receiver as invented by him, for the purpose of reproduction of speech electrically, is competent to do that work in all its particulars. The instrument I exhibit [*now put in evidence and marked " Defendants' Exhibit Reis Receiver No.* 1 "] is in all respects similar to those made by Reis, and with which I have repeatedly heard articulate speech, — not simply single words, but whole sentences,— and thus demonstrates what was highly probable *a priori*.

Reis then invented, as shown by his instruments, a transmitter able to transmit and a receiver able to receive and give out to the air such sounds as are meant when we speak of the transmission of speech by means of electricity. When, however, Reis described the operation of his own instruments he was somewhat in error, and all the descriptions of his instrument which I have seen which were published simply copied Reis's descriptions with their errors.

How Reis described the action of his telephone and how that telephone operated are very different things. We can to-day describe his instrument just as he left it, and, in order to know what it will do, we do not need to inquire about the terms in which he described it.

[*Adjourned.*]

BOSTON, May 17, 1883.

Reis's invention for us consists in what he made, not what he thought about it. His theory of the working of his instrument does not necessarily hold us to the same opinion, especially when we test his own instruments and find his description of their working wrong in some particulars. Thus Reis, in his theory, seems to imply that a current of electricity passing the movable terminals in his transmitter must be broken every time there is a vibration of the membrane, and this interpretation has been adopted, as was natural, by those who undertook to describe Reis's telephone by publications and by those whose interests to day will not be subserved so well by the true interpretation. But the descriptions of the *experiments* by Reis himself are sufficient to show that his interpretations of the working of his apparatus were wrong; for he says in his well-known prospectus, "Besides the human voice (according to my observations), the tones of good organ pipes from F to C, and the tones of the piano, can be reproduced equally well."

Now, for the transmission of such sounds as are given by a piano, it is as absolutely essential that there should be an unbroken current as it is that there should be such conditions for the transmission of speech. If there be any interruption of current in an attempt to transmit the tones of a piano, the tones will be interrupted, and will therefore not be transmitted. The sound of a piano consists in a continuous series of vibrations without intermittence. So do those of an organ, as well as those of the voice, and they cannot be transmitted in any proper sense if there be interruptions in the current. Now I have already described the Reis transmitter, and a simple inspection of the arrangement for producing changes in the current serves to show that, with such movable parts, where the motion of one depends upon gravitation in one direction as does this, while the other is compelled to move in any period by the action of sound vibrations, it will be seen that the motions of the former when separated from the latter cannot follow the motions of the latter, and therefore the latter may make many vibrations before the former may again fall to touch it; such vibrations of the membrane, however faithful they might be to the motions of the sound-waves which cause it to move, would be entirely lost from the possibility of reproduction, no matter what might be used as a reciver; when, therefore, Reis says that the tones of a piano may be reproduced, it is substantially the same as saying that the current has not been broken during such transmission.

Furthermore, it will be seen, by considering the possibilities of the motions of such parts of a transmitter, that not even pitch can be reproduced when there is such a break in the current as such a description would imply. The only pitch which could be reproduced would be that of the possible contacts per second of the two movable electrodes, which, as before stated, will depend, not alone on the motions of the membrane, but upon the rate of fall of the V-shaped piece after it has been separated from the lower connection by an upward thrust of the latter. This may easily be tested; connect the Reis transmitter with any receiver in circuit with a battery and produce sounds of such strength as to make certain that there is an actual break in the current, and what will be heard from any transmitter will not be pitch, but a rapid series of crackling sounds, which will differ but little from each other in character or frequency, no matter what the actual pitch of the sound may be at the transmitter. By lessening the intensity of the producing sounds, the terminals will have less amplitude of separation until, when pitch alone is faithfully produced, there will be no break in the current, though there may be a slight break of contact, a distinction to which I have before called attention.

Again, it is possible to demonstrate in another way that there is not necessarily any make or break of current in the Reis transmitter at the platinum terminals when the membrane is made to vibrate, for, by the substitution of a piece of carbon in the place of the mercury cup, where the function is simply to maintain contact, and not to effect the current, such modified Reis transmitter becomes immediately an excellent transmitter producing such a current as is competent to loudly and faithfully reproduce speech. This demonstrates that there is not a break of current at the platinum terminals, and shows what a slight change was needed in the apparatus of Reis in order to constitute it an excellent transmitter.

A Reis transmitter differing in no respect from the common Reis transmitter, except in the substitution of such carbon for the mercury, I have here [*now put in evidence and marked "Defendants' Exhibit Reis Transmitter Modified, W. A. C., Spl. Ex'r"*]. With this instrument it is possible to transmit speech well, which proves that during transmission there is not a break at the platinum terminals, but that an appropriate current traverses the circuit.

The chief defect in the Reis transmitter consists in the employment of platinum terminals, a substance which is easily fused when made a conductor in a circuit requiring a strong current of electricity, in order to operate the receiver at a distance; the terminals, being small, are apt to fuse together when a current of sufficient strength is employed in it. The principles involved in the Reis transmitter are no more changed by substituting a piece of carbon for a piece of platinum than it would be changed by substituting rosewood for oak in the structure of the box. By substituting carbon for the platinum in the Reis transmitter, one has not changed the mechanical conditions present one whit; but the change will make it a more efficient instrument. By substituting rosewood for oak it might be made a more elegant instrument. All of these considerations convince me that the common descriptions of the theory of the operation of the Reis telephone transmitter, so far as such descriptions refer to it as a make and break current device, are wrong. Before I had ever seen or experimented with such Reis apparatus, I had occasion to describe it in a little book on the telephone I published six years ago. At that time I described it in the same terms I found it described in other publications, and such description I have found, by experiment and reflection, to be wrong, and I repudiate such description as being wrong, both mechanically and electrically; and I say the same as to all the descriptions of the principle of working of the Reis transmitter which are substantially the same as those in that publication, whether such descriptions are by Reis or by any one else.

As to the Reis receiver, which I have before described as competent to transform electric vibrations of any sort into sound vibrations, through the action of magnetism, and which, I understand, has never been questioned by anybody as to its ability to produce in air sounds corresponding in all respects to the successive changes in the magnetism. The chief difficulty with this device is not in its electrical or magnetic relations so much as in its acoustic adaptations. It is an instrument made to sit upon a table like an ordinary telegraph instrument, as if Reis expected that the sounds produced by it might be loud enough to be heard by a room full of people, — an acoustical condition which is unfavorable for the hearing of weak sounds. If, instead of mounting his receiver in this way, it be so mounted as to prevent the scattering of sounds in all directions, as it will in this, and enable them to be utilized at the ear so that the minuter actions of the receiving magnet may be better heard, the receiver is then found to perform well, and speech may be heard nearly as well with such a receiver as with the best that have yet been invented.

[*Noon recess.*]

These two receivers [*now put in evidence and marked Defendants' Exhibits " Reis-Thompson Receiver " and " Thompson-Reis Receiver "*] are alike, excepting the resistance of the coils, and are examples of the receiver just spoken of.

In all the receivers so far mentioned the chief source of sound in air from them is due to the molecular movement produced in an electro-magnet by an electric current, such magnetic changes acting directly upon the receiving case of wood. But I find in a publication by V. Legat, which is referred to in No. 19 of the answer, a figure and a description of another kind of a receiver to be used with a Reis transmitter for the reproduction of sounds. Such receiver consists in an electro-magnet provided with an armature so mounted in front of the poles of the magnet that the changes in magnetism of the magnet act inductively upon the armature and cause it to vibrate in consonance with such magnetic changes. This inductive magnetism upon the armature, by which the latter is made to do the sonorous work, has the additional advantage over the other receiver of embodying not only the molecular movements of the magnet itself, but the attractive effect of such magnet, and it does not differ in any involved magnetic or electric relation from the receiver shown in Fig. 4. of

Prof. Bell's 1877 patent, No. 186,787. The vibrations of such an armature may have much greater amplitude than is possible for the electro-magnet itself to have, and therefore the strength of the resulting sound may be relatively increased. With such a receiver which I have had constructed for the purpose, I find that it is competent to reproduce speech in its entirety and with corresponding increase in loudness. Such an instrument I now produce [*now put in evidence and marked "Defendants' Exhibit Reis-Legat Receiver, W. A. C., Spl. Ex'r"*].

This instrument, which was invented in 1862 to be a receiving telephone, was evidently intended to sit upon a table rather than to be held to the ear, and because of that, when it so sits upon a table during use, it is not possible to hear distinctly the speech waves emitted by it, if one is at a distance from it; yet it is not difficult to make it talk loud enough so that it may be heard with tolerable plainness two or three feet away, and if it be held to the ear, every word will be plainly and distinctly articulated. When this device is so arranged that the air vibrations produced by it are concentrated at the ear instead of being scattered in all directions without changing in any degree its electrical and magnetic relations, it becomes the common magnet receiver, with the exception that in the common magnet receiver the magnet is a permanent magnet instead of an electro-magnet. All that has been changed about it is simply the boxing. There is nothing added, and nothing subtracted; but it is identical in everything excepting shape.

The good performance of such a receiver depends upon the relation of the varying electric current to the strength of the magnet, which will depend upon the relation of the resistance of the coils of wire to the resistance in the rest of the circuit, and the proper adjustment of the armature to the magnet, which adjustment is provided for in the original instrument and in the exhibited copy, Reis-Legat receiver.

Reis then invented an instrument for the transmission of sounds electrically, which instrument he named the telephone. He invented and constructed an apparatus suitable to be used as a transmitter, and also to be used as receiver. He declares them competent to reproduce any kind of sound, and especially speaks of the piano, the organ and the voice. He declares that spoken words could be transmitted, and had been by him; and I find by experiment with the same apparatus that it is competent in my hands to do the same that he said it would do; and, while I do not agree with him in some parts of his explanation of the working of his devices, I am persuaded that he invented a speaking telephone which is competent to transmit speech by means of a varying current of electricity, such varying current being produced by the change in resistance in such an electric circuit as could be produced by sound vibrations in air acting upon the electrodes of such circuit so as to vary the resistance of that electric circuit, and which electric undulations so set up were transformed into magnetic action in a suitable receiver, and through the action of the varying magnetism, either directly, as in the knitting-needle receiver, or less directly through inductive action upon an armature set up in the air vibrations corresponding to the air vibrations set up in the air at the transmitter.

This is precisely what is done, so far as transmitter is concerned, in what is now called the Blake transmitter. There has been a substitution of a thin metal plate for the membrane of Reis, the moisture of the breath causing the latter to very soon get limp. The present diaphragm prevents that, but has no different function. Carbon has also been substituted for platinum at the terminal, — a substance better adapted to that particular purpose than platinum, though the function is in no wise different. Carbon will not fuse, and is capable of yielding a better minute arc during the vibrations of the terminals than platinum will give. Beyond that, the instruments are identical, one being only an improvement upon the other, — in no wise a departure from the principle of the first Reis transmitter.

[*Adjourned.*]

[*Complainants object to all statements made by the witness as to what the Reis did do or did not do before the date of the Bell patent because the witness has no knowledge on the subject, because there is no foundation for such testimony in the answer, and because it does not appear when or where, if ever, Reis did or attempted to do anything stated by the witness; and object to all statements relating to the alleged work of Reis which are not found in or which is inconsistent* *with the publications referred to in the answer and put in evidence; and further object to the instrument marked "Reis-Legat Receiver," because it does not conform in the parts which it possesses to the description given in the Legat article, and because it contains features of construction which tend to adapt it for an articulate speech receiver which are not found in the Legat article, referring particularly to the paper put over the poles of the magnet, and to the piece of soft rubber between one of the poles and the armature which are in the instrument produced, and which are not described or shown in the article by Legat. And also object to the references to a so called boxed Legat receiver unless the instrument referred to is put in evidence. And further object to the said answer, for this, that the statements therein contained are contradictory of and inconsistent with the publications named in defendants' answer and put in evidence by the defendants.*]

BOSTON, May 24, 1883.

Int. 50. Please explain the electrical conditions in the use of the telephones of Reis, Wright, the Bell patents of 1876 and 1877, that in general use, and your telephone.

Ans. In all cases where electricity is generated and conductors are provided there the strength of the current in such conductor is correctly represented in the expression $\frac{E}{R} = C$, where E is electromotive force, R is the resistance in the circuit, and C the current travelling in such circuit. Now, inasmuch as the strength of the current varies inversely as the resistance, and as the resistance in the circuit is generally made up of two or more parts, it is customary to represent the resistances in different parts of the circuit by organ and the voice. He declares that spoken words could be transmitted, and had been by him; and I find by experiment with the same apparatus that it is competent in my hands to do the same that he said it would do; and, while I do not agree with him in some parts of his explanation of the working of his devices, I am persuaded that he invented a speaking telephone which is competent to transmit speech by means of a varying current of electricity, such varying current being produced by the change in resistance in such an electric circuit as could be produced by sound vibrations in air acting upon the electrodes of such circuit so as to vary the resistance of that electric circuit, and which electric undulations so set up were transformed into magnetic action in a suitable receiver, and through the action of the varying magnetism, either directly, as in the knitting-needle receiver, or less directly through inductive action upon an armature set up in the air vibrations corresponding to the air vibrations set up in the air at the transmitter.

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[*Adjourned.*]

[*Complainants object to all statements made by the witness as to what the Reis did do or did not do before the date of the Bell patent because the witness has no knowledge on the subject, because there is no foundation for such testimony in the answer, and because it does not appear when or where, if ever, Reis did or attempted to do anything stated by the witness; and object to all statements relating to the alleged work of Reis which are not found in or which is inconsistent* *with the publications referred to in the answer and put in evidence; and further object to the instrument marked "Reis-Legat Receiver," because it does not conform in the parts which it possesses to the description given in the Legat article, and because it contains features of construction which tend to adapt it for an articulate speech receiver which are not found in the Legat article, referring particularly to the paper put over the poles of the magnet, and to the piece of soft rubber between one of the poles and the armature which are in the instrument produced, and which are not described or shown in the article by Legat. And also object to the references to a so called boxed Legat receiver unless the instrument referred to is put in evidence. And further object to the said answer, for this, that the statements therein contained are contradictory of and inconsistent with the publications named in defendants' answer and put in evidence by the defendants.*]

BOSTON, May 24, 1883.

Int. 50. Please explain the electrical conditions in the use of the telephones of Reis, Wright, the Bell patents of 1876 and 1877, that in general use, and your telephone.

Ans. In all cases where electricity is generated and conductors are provided there the strength of the current in such conductor is correctly represented in the expression $\frac{E}{R} = C$, where E is electromotive force, R is the resistance in the circuit, and C the current travelling in such circuit. Now, inasmuch as the strength of the current varies inversely as the resistance, and as the resistance in the circuit is generally made up of two or more parts, it is customary to represent the resistances in different parts of the circuit by $R + R_1 + R_2$, and so on, the sum of all these being the total resistance in the circuit; and, in accordance with this usage, I shall explain the electrical conditions and currents in the several cases. In the Reis telephone there was provided a complete electric circuit in which the electro-motive force being provided by a battery was practically constant.

The resistance in that circuit consisted (1) of the resistance in the battery, which I will indicate by R. This is called internal resistance. (2) The resistance in the circuit external to the battery embracing the connecting wires is represented by R_1; (3) and in addition to this a variable resistance in the transmitter, which I indicate by $\text{\textsc{r}}_2$.

Now, letting E represent electro-motive force, the expression $\frac{E}{R+R_1+\text{\textsc{r}}_2}$ represents the electrical conditions employed by Reis. The introduction of this variable resistance $\text{\textsc{r}}_2$ constitutes Reis's great invention, as he was the very first, so far as I have any information, to vary the current strength in a circuit by means of a varying resistance operated by the energy of sound vibrations. It is precisely what is now known as microphonic contact.

In the case of Wright, who succeeded Reis, he also employed a constant electro-motive force such as from a battery, and a circuit having internal resistance $\text{\textsc{r}}$, an external resistance $\text{\textsc{r}}_1$, and a variable resistance R_2 so that the expression for his current stands thus: $\frac{E}{\text{\textsc{r}}+\text{\textsc{r}}_1+R_2}$. This represents the current in Wright's primary circuit. The letters marked $\text{\textsc{r}}$ and $\text{\textsc{r}}_1$ in this case I have made small to indicate their relative size when compared with the R's in the case of Reis.

In Reis the internal resistance in the battery which is represented by R may be very considerable, and will increase with every cell employed to obtain a stronger current, whereas in Wright the internal resistance $\text{\textsc{r}}$ is reduced to the lowest possible, and at no time need to exceed that in a single cell, as there can be no advantage in using additional cells.

The external resistance in Wright's primary is $\text{\textsc{r}}_1$, for this too is reduced to its minimum, and is indeed shortened up to a few feet in length; while the variable resistance R_2 is thus made to have a relatively much greater effect upon the variability of the current strength than was possible to be had with the Reis arrangement.

Wright practically brought both the transmitter and receiver of Reis close together, and, instead of using the magnetic variations of the Reis receiver to produce sounds, he utilized them in producing electrical undulations or vibrations in a secondary circuit which he provided.

This secondary circuit was so related to the primary circuit that a variable electro-motive force is set up in it, and the resistance in this secondary circuit may be represented by R (the internal resistance of the secondary coil) $+ R_1$, which represents the resistance in the rest of the circuit when a discharge is taking place, so that this electrical relation may be thus represented: $\frac{E\ (\text{var.})}{R + R_1}$

I have before explained that there are electrical conditions in the Wright receiver which are not utilized, and which, being present, would only serve to modify the other electrical relations upon the circuit. This condition may be thus represented: $\frac{E\ (\text{var.})}{R + R_1 + B_3}$.

The B_3 here indicates that the current strength upon the line is made smaller, not by the existence of a resistance proper, but by the filling up of the line, or the charging of the line until a discharge can occur, when factor B_3 becomes a minimum to be increased again as before.

In Bell's patent of 1876 and 1877, the currents were such as may be properly represented by $\frac{E\ (\text{var.})}{R + R_1}$; R and R_1 representing as before the internal and external resistance of the line. Here it is the electro-motive force which was a variable factor, while the resistances of the battery and of line and of instruments are constant.

In commercial telephones such as employ secondary currents the conditions in the primary are represented by $\frac{E}{R + R_1 + R_2}$, for the electro-motive force being provided by a cell is practically constant, while the internal and external resistances are brought to a minimum, and the variable resistance R_2 is made to be the greatest practicable.

It will be seen that this is precisely the same as the currents in Wright's primary.

In the secondary of the commercial telephone, the electro-motive force is variable, while R and R_1 are constant, which is precisely the same as the expression for the currents of Bell's 1876 and 1877 patents.

In my method the electrical condition in the primary are represented by $\frac{E}{R + R_1 + R_2}$. and are substantially the same as the currents in the primary of the commercial telephone and in Wright's primary.

In my secondary E is variable, while R and R_1 may represent the resistance in the secondary coil and the line to the receiver, but, inasmuch as no current can traverse my receiver, it follows that no expression for current strength can be given, and the nearest attempt would be the following: $\frac{E\ (\text{var.})}{R + R_1 + \text{infinity}}$, which, of course, will equal nothing.

The electricity operative in my receiver not being current but statical, its efficiency is represented by electrical attraction between the plates, and that by the formula $\frac{E^2\ (\text{var.})\ S}{8 \pi D^2}$, as has before been explained.

In any electrical instrument provided with a metallic conductor, like a wire, through which a current of electricity is to pass, the strength of the current at any instant passing through it will depend upon the difference of potential between the terminals and the resistance of the conductor, and that quite independent of the source of electricity. Thus, in a magneto telephone, if there be a difference of potential of one hundred volts between the terminals, and the resistance of the coil be one hundred ohms, the current that will traverse that coil will be equal to one ampére, in accordance with Ohm's law. $\frac{E = 100}{R = 100} = 1 = C$.

This is a correct representation of the action in all magnet telephones, the variable being E. R, always finite and always low, always gives a definite value to C. In mine, if $E = 100$, $R =$ infinity, and consequently C will be zero, which shows that it does not conform for its action to Ohm's law.

If we consider now the electrical conditions present in my secondary coil and transferring line when the latter is in connection with my receiver, it will be seen that such connections represent a condition in which electricity may flow into but not through, and where the further extremity of the transferrer may acquire the same potential as that of the terminal of the induction coil, and where, if there be any discharge proper, it must be back through the coil. Whatever electrical energy, in its statical form, is spent within the receiver, of course that energy, being spent, can no longer exist as electricity, and therefore there can be no reaction. The transferring line will then simply be a receptacle into which electrical energy of the statical sort may be poured which will have for its function to charge the whole line to varying degrees of potential as distinguished from varying degrees of current strength.

If it were possible to picture the electrical condition of two wires, one through which a current of electricity is flowing, as is the case when a magneto-telephone is being operated in the usual way, and the other wire in which it is impossible for electricity to flow through like a current but only able to fill it, such picture would represent for the former a given amount of electricity at the beginning of the transferring wire, which amount would be continually diminishing in quantity to the further extremity of the line in the earth, where it would be nothing; and if such flowing current were made up of vibrations or undulations, then such undulations might be represented like waves upon such wire. The amplitude of such waves would be constantly decreasing to the earth.

On the other hand, in my wire the electricity would be seen to be more nearly uniformly distributed throughout it · the distant terminal of the transferring wire within my receiver will never be zero; for my receiver, having been once changed by operation upon such a line, retains enough difference of potential between the plates to continually react upon the line, and may acquire a difference of potential considerably greater than the electric potential which operates them during the transmission of speech. Such transference of electricity capable of operating such receivers is generally known as currents of charge, to distinguish them from the ordinary currents, such as conform to Ohm's law, such as are designated by C in that formula $\frac{E}{R} = C$.

As heretofore, such currents of charge have not had any commercial value. They have not been studied, and have not had the particular nomenclature adapted to them as has been the case with the common currents. It is a mistake to consider the two as being identical, for they are not; but each follows its own laws, and is capable of producing effects not producible by the other; that is to say, a current of charge is capable of producing electro-static effects, while an Ohm's-law current is capable of producing magnetic, or heating or other effects.

[*Noon recess.*]

A current of charge differs from an ordinary current in another particular, which is important. A current of charge proper can only exist when the wire in which it exists does not form part of a conducting circuit. For this reason, such current of charge rapidly decreases in current strength from the fact that the difference of potential between the two ends of the wire becomes nothing. For instance, suppose a wire, one end of which is connected to an induction coil, the other end extending in free air; if there be now produced an electro-motive force, say of one hundred volts, between the induction coil and the free end of the wire, there will, at the first instant, at the coil end of the wire, start a current of the ordinary sort; and the strength of such current will depend upon the resistance of the wire as ordinarly understood; but, as such electromotive force cannot be discharged from the wire, the wire will begin to fill up; that is to say, the free terminal will now be rising in potential, and will continue to do so until the whole wire has attained the same potential practically as the terminal in contact with the induction coil. Whether it attains completely to that or not does not depend upon the resistance of the wire, but upon the electro-static capacity of the wire; that is to say, its ability to contain electricity. If its static capacity be small, as it would be in a short wire, or in a long, fine wire, then the electric potential would be practically the same throughout the wire. This charging current differs, then, from the other current in this, that it becomes less, not through the effect of resistance in the conductor, but from the fact that such charging current decreases the difference of potential between the two terminals, so that the current stops because there is no difference of potential. The wire is said then to be charged. This condition I referred to by B_3 in the expression for varying current, and in connection with such expression it may be seen that the value of B_3, may vary from zero to infinity. In an ordinary ring circuit the value of B_3 is zero; while in an open circuit it may attain its maximum.

A current of charge then can never do the proper work of an ordinary current, for the reason that no sooner does it begin to act than it begins to prevent the conditions for an ordinary current by narrowing the difference of potentials continuously until the difference is zero.

[*Complainants object to all statements made by the witness as to what Reis or Wright did do or did not do, because the witness has no knowledge on the subject, because there is no foundation for any such testimony in the answer, and because it does not appear when or where, if ever, Reis or Wright did or attempted to do anything stated by the witness; and object to all testimony relating to the alleged work of Reis or Wright which is not found in or which is inconsistent with the publications referred to in the answer and put in evidence; and further object to the said answer for this, that the statements therein are contradictory of and inconsistent with the publications named in defendants' answer and put in evidence by the defendants.*]

Int. 51. I must now ask you whether you have any knowledge, or in any one of your answers intended to imply that you had any knowledge, of the Reis, of the Reis-Legat or the Reis-Wright methods or apparatuses, except that derived from the publications put in evidence and your use of instruments made and used as described in those publications.

[*Complainants' counsel objects to the question, as it assumes that the witness used the instruments as described in the publications.*]

Ans. My knowledge of all of those instruments is derived either from publications describing them or from my own experiments with such instruments made as described. The instrument called the Reis-Legat receiver I find now has a piece of paper pasted over the poles, and a small bit of rubber is between the armature and one pole. Of these changes I was not aware when the instrument was put in evidence. This instrument has been used for experimental purposes a year or two and has been used in numberless ways.

The only object the paper over the poles could have would be to prevent the sticking of the armature to the pole when a strong current was used, and was thus only a partial substitute for a stronger spring attached to the armature. The function of the instrument as a receiver is not altered in its electric or magnetic relations in the slightest degree by such bits of paper, and they may be dispensed with and the instrument still be just what I said it was, — a good receiving telephone capable of reproducing speech perfectly; and there is no difference between this instrument and the original device as pictured in the Reis-Legat article in any electric, magnetic or acoustic relation other than this, that this one is not mounted upon a sounding board, as was the other. Beyond that there is no difference.

[*Adjourned.*]

BOSTON, May 25, 1883.

Int. 52. Prof. Cross, in one of his affidavits now shown you, seems to suggest some similarity between your apparatus and the apparatus described in the Bell patent of 1877, and referred to in the sixth claim of that patent, and Mr. Vail, near the close of his affidavit now shown, you testifies that your apparatus infringes the Bell 1877 patent: please consider this matter, and state whether there is anything in your apparatus, or any part of it, which is found in the Bell 1877 patent.

Ans. In Figs. 1 and 2 of Bell's patent of 1877 there is shown a box or cavity which contains a magnet with its coils, and the chief function seems to be simply a suitable boxing to protect such parts of the instrument, although it may be called a resonance box. In the front of this box there is fixed the speaking tube E, which is so contrived as to bring the whole force of the air-waves produced by speaking upon the middle of the inductive plate, when the instrument is used as a transmitter. Reis also employed a boxing in his transmitter, and in some forms shallow ones were employed instead of the cubical.

In my transmitters I use Reis's shallow chamber in the same manner as he did; and in my receiver there is no cavity behind the plate having any sonorous function, while in the front it is essential that the ear should come as close to the free vibrating front plate as it is possible to have it; and my receiver is not used as a transmitter.

In my opinion, both the gentlemen are mistaken if they would be understood that in my receiver the combinations are such as are shown in either of the patents of Mr. Bell, for I do not provide such a sounding box as is therein shown and set forth in the claims.

[*In pursuance of the objections made to answers* 49 *and* 50, *and in consequence of the statements of the witness in his fifty-first answer, that his knowledge of Reis's apparatus and work is derived entirely from publications referred to, complainants object to the statements in this last answer as to what Reis did or did not do, unless the witness* *shall point out the publication where he finds the description relied on, if any such exist, and the complainants particularly call upon the defendants to point out and put in evidence any publication made before the date of the Bell patent which shows what the witness calls a shallow boxing, if any such exist.*]

Int. 53. What knowledge or information have you as to what you call the Reis shallow boxing? You need not describe in your answer anything not published prior to 1877.

Ans. I have none excepting such as found in publications since 1877.

Int. 54. Disregarding all information derived by you from publications since 1877, state whether you desire to make any change in your answer as to the substantial identity of difference or your apparatus with anything found in the Bell patent of 1877, and in particular state what there is, if anything, in either of the Bell patents in suit, which even hints at any boxing, shallow or otherwise, of the electrodes controlled by the energy of air-waves.

Ans. I will only add that, so far as there are any likenesses between my apparatus and that in either of the Bell patents of 1876 or 1877, they are both derived in such particular from the Reis apparatus as described by Reis himself, and by others in publications already put in evidence, but, beyond those common likenesses, in all three the differences in structure, in mode of operation, in the factors involved, there is a radical difference, a difference so radical that the term itself needs emphasis in order to properly express the facts.

[*Complainants object to the reference to "publications," unless the passages relied upon, if any such exist, are pointed out, and they request that the same may be done.*

Complainants inquire whether the defendants do not intend to put in evidence and furnish to the court the other well-known publications relative to Reis made before 1876 *or* 1877.

The defendants answer that they will be pleased to have all publications of every kind known to complainants put in evidence so far as they may be deemed pertinent by the complainants, but that, so far as defendants' counsel has been able to examine publications relating to Reis and Reis-Wright, it is clear to him that the publications *already put in evidence contain all that is material, including all that makes against as well as all in favor of the defendants' view of the Reis and Reis-Wright methods and apparatus, and therefore he does not see the need of putting in any other publications than those put in in Int.* 49.

Both parties agree that certain of the articles are mere reprints of the others, and need be printed but once in the exhibits, as follows: —

The Reis-Legat article is numbered 19 *in the answer, also* 27 *in the answer, and is reprinted in Dingler, Vol.* 169, *pp.* 23–29, *part of No.* 28 *of the answer.*

Boettger's original article in his own paper, the "Polytechnisches Notizblatt," No. 33 *of the answer is reprinted in Dingler, Vol.* 168, *p.* 185, *part of No.* 28 *of the answer; also in the "Frankfurter Conversationsblatt," of June* 30, 1863, *part of No.* 31 *of the answer; and also in the "Polytechnisches Centralblatt,"* 1863, *No.* 32 *of the answer.*]

[*Noon recess.*]

Cross Examination by J. J. STORROW, Esq., *of Counsel for Complainants.*

Cross-Int. 55. In several passages in your testimony you have used the word "electrification," with reference to the plate in your condenser receiver, and you have spoken of the plate connected with the induction coil as "electrified" (I refer to pages 347, 348 and 367 among others); please state what you mean by "electrified" and "electrification" in that connection.

Ans. I mean by electrification just what is meant by electrification when a Leyden jar is connected with an electrical machine or other suitable source of electrification; namely, that the two coatings inside and outside will immediately assume a certain electrical relation, which is properly termed electrification; that is, one coating will become positively and the other coating negatively charged, so as to be capable either of attracting each other or of a discharge from one to the other, if a suitable conductor be provided. I have found by numerous experiments that when my receiver is so connected it becomes charged in such a sense that if it be separated from its connections and it be tested with an electrometer one of the terminals is found to be positively and the other negatively charged; and these two plates thus charged may have and retain for days a charge sufficiently strong and be capable of giving a spark an eighth of an inch long, which is precisely the condition a Leyden jar has when it is said to be electrified; and for that reason I employ the term.

Cross-Int. 56. What do you mean by "charged positively" in your last answer?

Ans. By "positive" I mean an electrical condition higher than that of the other which is opposed to it, and so called negative. I also mean more than that. I mean by "positively charged" that condition of the body in which a greater degree of electrification is present in the same sense as that same term is used when applied to the terminals of a battery, in which that difference, which we call electro-motive force, is mostly a difference in degree.

In my receiver either one of the plates may become either positively or negatively charged in precisely the same sense as a Leyden jar may, and I employ it always in such a sense.

Cross-Int. 57. What do you mean by "negatively charged" in your answer to Cross-Int. 55?

Ans. I mean this: that whenever any body whatever is brought into proximity to a body positively charged, the first body will have, through the action of what is known as electrical induction, a contrary electrification produced upon the face or side adjacent to such positively charged body, while the more remote side or face will have a corresponding positive electrification, provided no metallic conductor is allowed for the escape of such positive electrification. If such conductor is provided, such positive electrification will escape, leaving the body negatively charged or electrified. If it be not provided, then such body acted upon by a positively electrified body will still be properly an electrified body, although it might not be able to show a difference of potentials when considered by itself. That is a very common condition observed in electrical induction, and is a matter of common lecture-room experiments for showing, not the potential of the body, but the electrification of the body, by induction.

Cross-Int. 58. You have now stated, in answer to my three inquiries, in substance, that you consider a body "electrified" when it is "charged," and that is "charged" when it has "electrification." If you have any more definite understanding of what constitutes "electrification" or "charge," I wish you would state it.

[*The prefatory part of the question objected to as a manifestly unfair summary of the answers of the witness.*]

Ans. I did not apprehend that the question called for an explanation of what is meant by the term "electricity," but I will be more explicit, as it seems to be called for. In my former answers I have stated that electricity, whatever may be its nature, is always produced whenever two bodies of different physical or chemical constitution are brought in contact with each other. One of these becomes positively electrified and the other negatively electrified, as those terms are commonly used. These two differently constituted bodies, which have been thus touched together, have had developed a certain new physical condition, by which they now will react upon each other in a way very different from the way they would before they were touched. They now will attract each other. This attraction is due to that physical condition which is called electrification, and the agency through which this new action takes place is called electricity. The two terms, positive and negative, are conventional, and serve chiefly to point out differences in electrification; so that again I say, that by "electrification" I mean that physical condition imposed upon a body or bodies by means of which what we call electrical phenomena may be made apparent.

Cross-Int. 59. Suppose you detach the frame and back plate, and connected metallic mass of your receiver, leaving only the front plate attached by the line conductor to the terminal No. 1 of the induction coil in your apparatus, can you charge or electrify that plate in the sense that you have used the words "charged" or "electrification"?

[*Objected to because the term "connected metallic mass" has no application to Dolbear receiver No.* 1, *and yet the question is not otherwise limited to either receiver, and therefore is ambiguous.*]

Ans. Certainly I can; for if a source of electricity is made to act upon such plate the distribution of potentials through such conductor will electrify the whole conductor, including the plate. The only difference will be in degree. When such a body as the back plate is in close proximity to the front plate, a greater degree of electrification will be made possible upon the front plate, but its absence does not entirely prevent the front plate from being electrified. It may be noted here that both of the plates are coated with varnish which is known as a dielectric, which is a substance capable of absorbing electricity and holding it a long time; and I have proved repeatedly that such as I employ for my plates are capable of absorbing and retaining for days an electrification capable of demonstration; and that this is so is not in discordance with known electrical laws, but in strict conformity to them.

Cross-Int. 60. Is it your notion that it aids the operation of your receiver in reproducing speech to have the front plate coated with a substance which prevents it from quickly and readily yielding up its charge?

[*Objected to because of the confusion in the question between the charge due to the electric potential of the secondary coil and the transferrer in the use of the receiver, and the charge of the dielectric coatings.*]

Ans. It is in accordance with my notions derived from experience that when the plates are coated with a substance capable of dielectric action, that the first electric energy supplied to the plate is absorbed by such dielectric, and for that reason speech reproduced is considerably weaker than it is when the instrument has been in use long enough for the plates to become properly charged by absorption, and after that the chief reaction appears to be altogether without absorption, and by so much more perfect and entire. This condition of absorbed electricity, that is to say, electricity provided for absorption for charging the plates, may be provided either by the instrument itself or by any external provision, generally the latter.

Cross-Int. 61. When the front plate has become properly charged by absorption, is it positively charged or negatively charged?

Ans. It may be either the one or the other, but it is a matter of very common experience that when such a receiver is first put in connection with the transmitter, and talking begun, that one may hear the charging process going on until it has attained its maximum; but I have never taken an instrument out from such circuit to test it at the time in order to discover whether the front plate had been charged positively or negatively. I conceive that whether it was the one or the other would depend upon the connections in the primary circuit.

Cross-Int. 62. When your condenser receiver is reproducing speech, is the front plate which is connected to the line positively charged with electricity, or negatively charged?

Ans. Here are two questions, though apparently but one. If the front plate has been positively charged, no matter how, at the beginning of the talking with it, then it will be positively charged throughout the whole of the talking. *Secondly*, the electricity operative to change the electrified condition of the front plate may be and generally is a succession of electrical pulses both positive and negative, which react upon the already positively charged front plate, and so will change the degree of positive electrification existing there. If the front plate was negatively charged at the outset it would have remained negatively charged in the same sense; and what I have said of these changes can be demonstrated with any of my receivers by testing them with an electrometer after such action.

Cross-Int. 63. Do you mean that the electrical pulses which succeed each other are both positive and negative at the same time, or are alternately positive and negative?

[*Objected to as unnecessary, the meaning of the answer being entirely clear.*]

Ans. I didn't mean either the one or the other, because those conditions called positive and negative may succeed each other, differing only in degree as more or less positive, more or less negative, or alternately positive and negative. They may follow each other in all orders.

Cross-Int. 64. Suppose terminal No. 2 of the induction coil be connected to earth and terminal No. 1 of the induction coil be connected to the front plate of your condenser receiver No. 1, nobody talking to the instrument, and the back plate of your condenser receiver connected to earth, what will be the potential of the front plate and what will be the potential of the back plate?

Ans. There are here two cases, —

First. If the plates of the receiver have never been used, that is to say, have never been charged, and they are connected as described in the question, their potentials will be zero.

Secondly. If they have been charged by previous usage or in any way so that the dielectric has absorbed a certain amount, then each plate will have a potential which will be due to such electrification, there will be an electro-motive force between the plates, and if they are left in the condition described for some time, there will be a flow of electricity through the conducting wires from the plate positively charged to the ground, and from the ground to the negatively charged, until both plates become of zero potential, but which occurrence in my instruments when properly charged may require several days to effect.

Cross-Int. 65. Suppose the plates, with the connections stated in the last question, had been left at rest for several hours, or are entirely new plates, and the transmitter then be spoken to and speech be transmitted by the apparatus, will the front plate be positively or negatively charged during the transmission?

Ans. If by speech here could possibly be meant what could be transmitted by a single pulse, suppose such an one to be positive, then such positive pulse positively electrifying the front terminal it might properly be said to be a positively electrified plate; similarly for a negative pulse; but when a series of positive and negatively recurring charges act upon the front plate, provided they exactly neutralized each other, — by which I mean that the sum of the positive charges was just equal to the sum of the negative charges, — then for that interval the front plate might be spoken of as not electrified; but then the case would be a particular case and might need explanation; but if in the performance of the transmission of speech electrical absorption could take place, as it certainly must take place whenever an absorber is provided, then whether the plate should be positive or negative would depend upon which condition had been absorbed in that plate, and that in turn would depend upon other conditions than simply that of the transmission of speech. It is hardly possible, on account of the electrical relations of the parts of my receiver, that it should be in condition to reproduce speech mum; but I have never taken an instrument out from such circuit to test it at the time in order to discover whether the front plate had been charged positively or negatively. I conceive that whether it was the one or the other would depend upon the connections in the primary circuit.

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Cross-Int. 65. Suppose the plates, with the connections stated in the last question, had been left at rest for several hours, or are entirely new plates, and the transmitter then be spoken to and speech be transmitted by the apparatus, will the front plate be positively or negatively charged during the transmission?

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Cross-Int. 66. It requires a series of positively and negatively recurring charges acting upon the front plate to transmit a single syllable with your apparatus connected as stated in your last question, does it not?

Ans. It does; but that is not what I meant by a single pulse. A single syllable of such short duration will perform in its degree what a longer one or a whole sentence would do.

Cross-Int. 67. How many times a second do these successive pulses recur when a man is speaking into the transmitter?

Ans. If the pitch of the voice is about that of my own, as I am talking now, their rate per second will be about one hundred and twenty, that is to say, they will follow each other one hundred and twenty times per second for the fundamental sounds in my voice. For the higher or overtones, two, three, four, five and so on up to ten or twelve times the same number per second, making the full quality of tone constituting my voice; so that for so short an interval as the hundredth of a second there would be necessarily quite a number of such pulses that should actuate the receiver.

Cross-Int. 68. Then, if I understood your explanation, when the receiver has its two plates connected to ground as described, and the apparatus is talked to, the successive impulses drive positive and negative charges alternately into the front plate of the receiver. Is that your meaning? If not, please state what it is on that subject.

Ans. So far as the transmitter and the transferring line is concerned, I mean to say that positively and negatively recurring charges are sent upon the line to the receiving plate; but I do not mean to imply that the plate subject to such charges and such changes from the transferring line itself becomes first positively charged and then negatively charged in the same sense as does the transferring line, because such receiving instrument is an electrical instrument having other functions than simply to receive or discharge in this way or that the electrical charges which are provided for it.

Cross-Int. 69. In the ordinary operation of your apparatus connected as described and transmitting speech, do you consider that the front plate is always charged with the same sign during the tramsmission of a sentence, or that its sign changes during the transmission of a sentence; or what is your meaning on that subject?

[*Objected to because of the confusion between the charge of the metal part of the plate varying with the charge of the transferrer and the charge of the dielectric portions or coatings of the plate.*]

Ans. This question seems to imply that the plates in the receiver may completely lose their charge after a sentence has been given out by it, and that the succeeding charge of the plates depended upon the initiatory pulses of the succeeding sentence, a condition of things which not only does not exist, but which I took pains in my answer a little while ago to say did not exist; but when the plates had once been charged they might retain that same charge for days, although no speech was transmitted in that time.

Cross-Int. 70. Do you think they would retain that charge for days if both were connected with the earth, as stated in the last question?

Ans. I know by experience they will. I do not mean to say that they will retain the same degree as at first, but that they will retain enough charge to prove its existence with an electrometer, and for the purposes stated.

Cross-Int. 71. Is the charge which you here refer to the residual charge which remains in consequence of and after the ordinary operation of the instrument connected as described?

Ans. It is residual in the same sense as is the residual charge in the Leyden jar, and it may be observed in my instruments when connected as described.

Cross-Int. 72. Considering the instruments when connected as described, — that is, both plates to the earth, — do you wish the court to understand it as your opinion that the residual charge remaining after the transmission of one sentence is so strong or great that the sign of the charge of the plate will not be reversed by the pulses of the opposite sign during the transmission of a second sentence?

Ans. What is understood by the term absorption which is called the residual charge is a phenomenon which requires time; for instance, if a body capable of electrical absorption absorbs electricity with any sign, for, say, five minutes, no single pulse of an opposite sign lasting but a fraction of a second, or even for a longer time, can discharge that electrification which it has absorbed, and therefore if in my receiver the plates have become charged at all, it is because the element time has been a factor as well as electro-motive force; and no single pulse or series of pulses from the transmitter can discharge that so as to produce in that plate an electrification of an opposite sign.

[*Adjourned.*]

BOSTON, May 26, 1883.

Cross-Int. 73. What is the resistance of the secondary helix of the induction coil belonging to your transmitter put in evidence?

Ans. I do not know what that particular one is. Mr. Buck has just measured it and informs me that the resistance in the primary coil is $\frac{14}{100}$ of an ohm, and in the secondary wire is 2,700 ohms.

Cross-Int. 74. Please state the length of the core and its diameter; also of the coil.

Ans. The length of the core is about five and a half inches; the diameter of the core a half an inch or five eighths; it is made of a bundle of wires, as is common in induction coils for all purposes.

The size of the secondary coil is four and a half inches long, an inch and three quarters diameter, wound with No. 36 wire.

The length of the primary coil is the same, and wound with No. 14 wire.

Cross-Int. 75. What battery do you use with this instrument?

Ans. Any battery may be used; but for my experimental line at home, between my house and the college, a distance by wire of nearly half a mile, I have employed one chloride of ammonium cell, such as is known as the Maynard cell, at each transmitter, which is a suitable battery.

The electro-motive force of such cell is nearly one and one half volts; while the internal resistance is or should be not greater than one ohm, and is better for this purpose when it is made less.

Cross-Int. 76. Can you tell me the weight of the moving parts that constitute the upper electrode, and the normal pressure between the two electrodes stated in grains?

Ans. I have never weighed such piece to know what either weight or pressure of parts is, and no particular pains has been taken to make such parts of a given weight or pressure, and in such parts as I have used I know they have varied in weight as much as three or four times, and this particular arrangement is one adopted for stability rather than weight; but I will have it weighed and the pressure determined. I have had Mr. Buck weigh these, and he reports that the weight of the upper electrode is four hundred and sixty-five grains, and that the pressure between the electrodes is fifty-seven grains.

Cross-Int. 77. When the transmitter is connected with such a battery as you have described, in the primary circuit, terminal No. 2 of the induction coil grounded, and the wire constituting terminal No. 1 left free in the air, do you know how much, or about how much potential is developed at the free end by speaking into the transmitter in such a manner as should ordinarily be practised in transmitting speech by it through one of your receivers?

Ans. The electro-motive force which is developed in such secondary circuit will in any particular case depend upon the change in current strength at that instant in the primary wire, and it will be its maximum when such change in the primary wire is instantaneous and the current entirely broken.

Intermediate changes will be proportional to the rate of change (by which I mean the amount of change in a given interval of time) in the primary current, and therefore it is not possible to speak of a change in electro-motive force with definiteness in such a case. I have, however, at various times, attempted to measure the developed difference of potential when the current was made or broken, both instantaneously and gradually, with this result: That under such conditions, when discharge by means of current is rendered impossible, by having terminals free in air, that the electro-motive force was, in the particular experiment that I have in mind, I think, about twenty-seven hundred volts. This was electro-motive force developed when the current in the primary was broken as instantaneously as possible by hand with a telegraph key. When the circuit was broken gradually, or was not entirely broken, but the current varied by varying pressure upon the key, the electro-motive force varied, but in so irregular a manner that no given indication could be duplicated.

These last conditions were not dissimilar to the conditions found in the transmitter when spoken to, except in this, that the varying pressures brought about by speech waves may be much more nearly equal in strength and variability than two consecutive touches by the hand can be in pressure.

Cross-Int. 78. Then, as I understand you, you have not been able to satisfy your mind as to the amount of potential developed under the circumstances stated in the last question, have you?

Ans. I have satisfied myself by experiment with large coils and with small coils in such comparative way that the electro-motive force or the difference of potentials developed is greater in the large coils than in the small coils, for, under similar conditions to those described in my last answer, the difference of potentials developed in a small coil of about one hundred and forty-three ohms was about seventy-five or eighty volts; but aside from that I am satisfied from the theory and laws of electricity involved in such development of a difference of potentials that the larger coil will give the greater difference. A great deal of time and ingenuity has been spent by many electricians in the attempt to measure with even approximate accuracy the difference of potential developed by induction coils, and in general it is known that with a given change in current strength and in magnetism in an induction coil a greater difference of potential will be developed in a large coil than in a small one; but no electrical apparatus maker can make an induction coil and label it as capable of developing a certain definite electro-motive force with a given change in its primary coil, and the only attempt towards that is the statement that such a coil may give a jumping spark of half an inch, or six inches or two feet, as the case may be.

Cross-Int. 79. Do you know whether the two terminals of the induction coil in your transmitter will yield a jumping spark in free air from one to the other when the transmitter is spoken to as stated in Cross-Int. 77, with the same battery specified in that question, and the two terminals brought into such close proximity as may be desirable without touching?

Ans. I have never observed such spark under such conditions as those, and it is highly probable that no such spark would pass unless the terminals were exceedingly near to each other, say one millionth of an inch or less, a distance too short for common measurement.

Cross-Int. 80. When a battery circuit containing two or three cells of ordinary battery, and containing an electro-magnet, is suddenly broken, a spark is generally observed at the instant of breaking, a familiar instance of this being drawing a wire connected to one pole of a battery across a rasp or file connected with the other pole of the battery. What is this spark attributable to?

Ans. This spark is due to the discharge of magnetism from the electro-magnet reacting upon the coil of wire surrounding it, and which is properly called a magneto-electric phenomenon, and as the discharge is practically instantaneous, the electro-motive force of such discharge is considerably higher than that of the battery which made the magnet first, and therefore gives a jumping spark in air which the battery might not be able to give.

Cross-Int. 81. If, instead of putting the electro-magnet in the circuit, you were to include several miles of wire, for example, in the circuit, the same number of cells, would you get a spark on breaking the circuit; and to what would it be attributable?

Ans. Such a spark may often be observed in breaking connection between the long wire and the battery, and such spark is in this case due to the electricity resident in the wire as the charge, and may be measured by what is called the static capacity of the wire; and unless such wire was exceedingly long, by which I mean thousands of miles, such discharge would be practically instantaneous, and that, too, like the other, might have, and generally would have, an electro-motive force exceeding that of the battery which charged the wire.

[*Question being reread.*] I did not understand the case to be that of a closed circuit. In the latter case a spark would pass, but not so large a spark as might under the other condition I supposed, and the spark that did pass would represent a current due to the static capacity of the long wire in air, which, being electrified, would tend to distribute its electricity on breaking of contact in both directions; that is, backwards through itself, as well as forwards towards the broken part when the electro-motive force present was sufficiently strong to overcome the resistance of an exceedingly short interval in air.

Cross-Int. 82. Does the phenomenon known as the extra current have anything to do with producing the spark in either of the two cases named in my last two questions?

Ans. The term "extra current" is often employed to express or to give name to this phenomenon of discharge. In the first case, where a magnet is enclosed in the wire, the convolutions of wire in the coil about the magnet have such relations to each other as to induce in each other electro-motive force in one direction or the other, and so give rise to currents due to such action, a condition which would not exist in a wire without convolutions; but if either wire, or any wire, is in any way electrified, and the source of the electrification, or the source of the current strength within it, be withdrawn, the electricity present will discharge itself in the way stated.

Cross-Int. 83. The extra current developed on breaking the circuit through which a current from a battery has been flowing is sometimes spoken of as a special current, which owes its existence to the sudden stoppage of the battery current, and which is of much higher electro-motive force than the battery current, and therefore produces a spark. Does any such phenomenon take place in the circumstances stated in my two questions?

Ans. The mere fact that a current of electricity has been stopped, in itself, alone, is not a cause for the existence of this extra current, although it is generally thus stated. In any wire through which a current of electricity is flowing, there will be at any instant in that wire an amount of electricity which will be proportional to its electrostatic capacity and the difference of potential between the points taken; and that quantity of electricity is a certain, definite quantity, and if no provision is made for maintaining it and provision is made for its escape it will immediately escape as a current in the direction provided. If the electro-static capacity be considerable and the resistance small, the electro-motive force will likewise be correspondingly great or greater and may produce a jumping spark in air.

Cross-Int. 84. Then do you mean that the jumping spark which is usually observed on breaking a battery circuit composed of a long line of wire not coiled upon itself and which includes one or two cells of battery, is due simply to the outflow of the electricity which the battery has poured into the wire, and depends for its amount upon the electro-static capacity of the wire, or what do you mean in that respect?

Ans. I mean to say that the electricity that constitutes this extra current only represents the electric energy which the wire has acquired from the battery, and the amount of which will depend upon the length of the wire, its diameter and the presence or absence from the neighborhood of the wire of bodies upon which such currents may act. The current of electricity through the wire has done work upon that wire and continues to do so so long as the current passes.

By "work" I do not mean the mere heating effect of the current, but do mean the change of position of the molecules when constrained to move by the presence of electricity, and this extra current is simply the reaction of molecules while assuming their normal conditions after constraint.

Cross-Int. 85. What do you refer to by the phrase "presence or absence from the neighborhood of the wire of bodies upon which such currents may act"?

Ans. I mean what is involved in what is generally known as Ampère's laws concerning the action of currents; for instance, a current of electricity traversing one wire exercises an attractive effect upon an adjacent parallel wire in which a current of electricity flows in the same direction as the first, and such attractive effect between the wires may result either in the actual motion of the wires towards each other; or, if that is not possible, currents will be developed in each wire due to such attractive action, and generally both phenomena will take place, but in any and all cases any effects that will be produced, whether attractive or other, will be at the expense of the electric energy acting.

Cross-Int. 86. Suppose the circuit consists of a mile or two of wire without convolutions, includes a couple of cells of battery, and after the current has been flowing through it, be suddenly broken close to the positive pole of the battery, in which direction will the extra current flow at the point of breaking?

Ans. It will flow towards the cells at that point.

Cross-Int. 87. Suppose with the same circuit the break be made close to the negative pole of the battery, in which direction will the extra current flow?

Ans. In either case it would flow in the opposite direction from the battery current; but if means are provided for measuring the amount that flows in such opposite direction at the junction of the battery and the wire, a greater quantity will be found to move in such opposite direction through that point when the break is made at the negative end than when it is made close to the positive end. In an experiment made with wires but a mile or two long, the difference would be but slight, unless such wires were impracticably large; but if such experiment could be made with wires some hundreds of miles long the difference would be very noticeable.

The reason for there being a greater amount of electricity that should pass such positive point, when the arrangement is such that the discharge from the whole of the external circuit is made to pass through it, rather than when it is prevented from so doing, except in part, is that such discharge takes place in the external wire in both directions when the break is made close to the positive pole, because the positive pole in the battery is in electric connection by means of the fluid and the other parts of the battery with the wire which is to be discharged; and if it were possible to break the circuit so quick that a portion of this could not escape in the short interval in which the terminals are exceedingly near together, but do not touch, — that is to say, conduction is stopped, — then such discharge would take place wholly in the other direction from the necessities of the case; but as we can never move such parts of a conductor with anything like the necessary speed, it follows that the discharge takes place as we see, and as a reverse current. In the other case, the broken terminal, fully charged to the same potential at which it was at the instant of being broken, will do work in creating what is called the electric field, which has before been explained, and which will give rise to a current in the opposite direction to the original battery current.

[*Noon recess.*]

Cross-Int. 88. Do you mean that this phenomenon of the spark is caused by the extra current or discharge which passes between the terminals during what you have described as the short interval when they are exceedingly near together, but do not touch at the instant of separation?

Ans. I mean that it is the phenomenon of discharge which takes place at that point the instant after such terminal has been separated from the charging terminal of the cell, so that the potential of the line terminal at that point is no longer maintained by the cell itself.

Cross-Int. 89. In your eighty-sixth answer you said that the extra current in the stated circuit would, if the circuit were broken close to the positive pole of the battery, flow towards the cell at that point. In which direction will it at the same time flow in the unbroken part of the circuit near to the negative pole of the battery?

Ans. There is a good deal of difficulty in stating what takes place in such a circuit on account of the idea which the term "current" itself conveys to the mind. In such a circuit as described, if the external wire may be supposed to be 200,000 miles long, or of such a length as required one second for an electric impulse to travel through it, then at the instant of breaking that circuit at the positive terminal the current at the negative end, or anywhere in that neighborhood, would continue to flow in the same direction it flowed before such break was made, because any change in the electric arrangement at such positive terminal would require a second to make itself felt at the other terminal. But if such circuit was exceedingly short, being but a mile or two in length, the interval between breaking the circuit and the effect of that break throughout that circuit would not be a measurable interval; and what we should observe would be an inverse current through the whole of such continuous part of the circuit, not because the other effect did not at first take place, but because the interval was too short for observation.

Cross-Int 90. Suppose you increase the electro-static capacity of the circuit by employing a long submarine cable for it. Would the electro-motive force of the extra current be thereby increased or not?

Ans. In a submarine cable the electric conditions are so very different from those in an aerial line of wire that they can hardly be compared, for electro-static capacity in the cable consists of several elements, the chief of which is that of the dielectric employed, and for the reason that the dielectric in this case absorbs a certain per cent of the energy of an electric impulse, it follows that the reaction of that dielectric upon the cable itself, tending to generate a current of electricity in the opposite direction from the original current, will give to the discharge an element of time, and the electro-motive force of such discharging current may not be so great as that of the initiatory charge. I have never experimented with cables of that sort, and so cannot speak of their performance with that practical knowledge which others may have.

Cross-Int. 91. In your fiftieth answer, p. 391 and the following pages, you speak of "currents of charge." Are there such "currents of charge" in any part of your apparatus when it is transmitting speech; and if so, in what part?

Ans. There are such "currents of charge" in the transferring wire from the induction coil to that plate of my receiver connected to that wire. If the other plate of the receiver be connected to the ground by a wire there will be corresponding currents of charge and discharge in that part.

Cross-Int. 92. In which direction are these currents which flow from the induction coil to the connected plate of the receiver?

Ans. Such currents of charge will be to and fro upon the wire.

Cross-Int. 93. And about how often do they alternate when you are speaking into the transmitter?

Ans. If the undulations caused by the fundamental tones of my voice are meant, these vibratory currents of charge will recur a hundred and twenty times per second, or thereabouts, for my voice. If overtones are referred to, then they may succeed each other as many as a thousand times per second; and in general, between those limits the number of vibrations in the charging current will take place.

Cross-Int 94. At the instant when the terminal of the induction coil connected to the line wire is at the highest potential given to it by the action of the transmitter, in which direction will this flow take place?

Ans. It will flow towards the receiver.

Cross-Int. 95. When the same terminal of the induction coil is at its greatest negative potential, in which direction will the flow take place?

Ans. Its direction will be towards the coil.

Cross-Int. 96. When this flow is from the coil towards the receiver in the case stated, what effect does it have on the potential of the connected plate?

Ans. It will tend to raise the potential of the metallic part of the plate.

Cross-Int. 97. When this flow is from the plate to the negatively electrified terminal of the coil in the case stated, what effect will it have on the potential of the plate?

Ans. The potential of the metallic part of the plate will be lowered.

Cross-Int. 98. Is it the potential of the metallic part of the plate, or the potential of the varnish on it, which is the efficient agent in the production of speech in your receiver?

Ans. Both of those conditions are essential for a good receiver, and they cannot be divorced in that way. It is the reaction of the varying recurring charges in the metallic part of the plate upon the dielectrical varnish, or air, or both, which is the chief factor for efficiency in my receiver.

Cross-Int. 99. Do you mean that your receiver would not be a good receiver if the plates were not varnished?

Ans. It would not be near so efficient a receiver without it.

Cross-Int. 100. Why did you not mention this important part of your receiver in your affidavit or in your direct examination?

Ans. I do not now think of any particular reason why it was not mentioned.

Cross-Int. 101. What particular electrical operation does the varnish perform which is left undone, or is imperfectly done, when the plates are not varnished?

Ans. The varnish being what we call a dielectric and capable of absorbing in a high degree the electrical condition of the metallic plate upon which it is spread, and retaining that condition for so long a time as to be a surprise to myself and to every electrician to whom I have pointed it out, furnishes what may be called an electrical resonator or sounding board, if I may borrow such an expression from acoustics, and the reaction appears to be mainly between the metallic parts of the plate, which may have their potential rapidly varied, and the electrical dielectric, which, as I said in a former answer, were capable of absorbing and retaining an electric charge that should last for days, and thereby keep the metallic parts of the plates charged by induction for the same length of time.

Cross-Int. 102. What do you mean by this "reaction," and how does it aid in the transmission of speech?

Ans. I mean by it what perhaps I can best state by analogy. When an undulatory current of electricity from a transmitter is made to act upon an electro-magnet, it is well known that the efficiency of the latter as a receiver is not so great as is the efficiency of the same current when made to react upon a magnet that is already permanently charged. The reaction in this case is between the varying current and the already developed magnetism. So in my case, the efficiency is greatly increased when, instead of making each electrical pulse to do its work upon the plates, it does its work upon the electrified parts of the plates, which are thereby rendered much more delicate and sensitive, and such electrified dielectrical surfaces are in my system what permanent magnets are to Bell's system.

Cross-Int. 103. What do you mean by the "electrified parts of the plates"?

Ans. I mean this: My plates consist of thin metallic disks coated with a varnish which is dielectrical in its properties, and when two of those plates are placed adjacent to each other as they are in my receiver they become as a system just like a Leyden jar.

It is well known that if a Leyden jar be so constructed that its metallic coatings can be removed, that if it be charged while they are in their proper place and then the metallic coatings be removed, the glass dielectric retains the charge and the metallic coatings may be handled at pleasure. When again put together the jar may be discharged as though it had not been taken apart, thereby showing that the electricity was in the dielectric and not in the conductors. In a similar way, when my two plates are charged the charge resides chiefly in the dielectric varnish coatings, so that although the metallic parts of the plates may be connected to the ground, the dielectric parts of the plates will not necessarily be instantly discharged, as would the metallic parts of the plates, and such residual electricity within the dielectric is the electricity of continuous charge of the plates to which I have referred.

[*Adjourned.*]

BOSTON, May 28, 1883.

Cross-Int. 104. Will you please state in what part of your plates, if there is such a distinction, the attractive power which causes the acoustic vibration is found, or chiefly found, during the operation of transmission of speech?

Ans. I think it to be somewhat difficult to say that it is in one part or in another part, but when the plates are electrified by conduction, so that one is positive and the other negative, the two plates as wholes attract each other, but I imagine the chief source of the attraction under this condition to reside chiefly in the dielectric. When the conducting part of the plates receives from the transmitter varying charges, the reaction between the plates, I think, to take place chiefly between the metallic parts, as such parts are more easily affected by the electrical changes transmitted to them. By "more easily affected" I mean what is implied by the term "conductivity." The metallic parts of the plates are more quickly charged and discharged than are the dielectric parts of the plates.

Inasmuch as these plates, when electrified as wholes, attract each other, whether the metallic part of the plate be in connection with the ground through the coil or not, it follows that the varying charges received from the coil must react upon the electrified parts of the plates first to change their electrical condition; and, in my opinion, such electrical action takes place before the attraction between the plates can be altered; but as this whole process takes place with such great rapidity, no appreciable interval could be observed, and it is theoretical when stated as I have stated it. What I mean is that the *order* of changes is as I have stated, — that the electrical change upon the dielectric must precede any motion of either plate due to attraction.

Cross-Int. 105. You have given the formula $\frac{E^2 S}{8 \pi D^2}$ to express in general terms the attraction between the front free plate and the back substantially rigid plate of your receiver. Is that the well-known formula long applied to Thompson's attracted disk electrometer?

Ans. That formula I have taken bodily from the books as expressing the attraction between parallel plates when electrified, but which formula I have never verified by experiment.

Cross-Int. 106. In your ninth question you were asked to point out an instance of an apparatus in which motion of the armature at one end of the line gave rise to corresponding motion of the armature at the other, and you referred to the Gauss and Weber device. Will you please point out where you find an armature at the transmitting station, or where you find either armature or electro-magnet at the receiving station in that device?

Ans. In the transmitting apparatus of Gauss and Weber the coil which surrounds the magnet is made to move in the magnetic field by motions of the hand, and so has two functions, — that of the coil itself and that of the armature proper. When the coil is fixed and not susceptible of relative movement, an iron armature might be employed to effect precisely the same results; that is, setting up an undulatory current within the circuit, including the coil. A movable coil upon a magnet is a well-known substitute for the other.

In the receiving instrument it is the reaction of the current upon the included magnet which causes the latter to move this way or that, but it is without an armature or a substitute.

An electro-magnet consists of either a simple helix or solenoid or a combined helix and a piece of iron or steel within it in such position as to be affected by the current traversing the coils. It is proper to speak of a galvanometer as an electro-magnet, and that, whether the core, so called, be fixed or movable and whether the cores be of soft iron or permanently magnetized steel. The shape of an electro-magnet varies with the purpose to which it is adapted, and as in the receiver of the Gauss and Weber there is shown a magnet enclosed in a coil of wire which is to be affected by currents of electricity traversing such coil from a magneto-electric transmitter I think it proper to speak of such receiver as one form of electro-magnet.

Cross-Int. 107. The receiver of Gauss and Weber is a reflecting galvanometer, is it not?

Ans. The one figured in the book to which I referred in my ninth answer purports to be a reflecting galvanometer.

Cross-Int. 108. If you know of any passage of any respectable writer which speaks of a reflecting galvanometer as an "electro-magnet and armature," I wish you would point it out.

Ans. The name that is given to an instrument is generally not a descriptive one, but has more often to do with the function of the instrument, as is the case with the galvanometer, and if a respectable writer did not speak of it in the way mentioned it would not follow that it was therefore not appropriately applied to the device.

Cross-Int. 109. Can you point out any passage in any writer who does apply to the galvanometer the term named in my last question?

Ans. I cannot, and neither can I find the name "telephone" applied to an ordinary telegraph relay. It is, nevertheles, properly applied, if anybody chooses to use such an expression.

Cross-Int. 110. Do you think you would have conveyed a correct idea to the court if you should in your deposition given to-day testify that Morse had made and used an electric telephone before 1850?

Ans. I think I should be quite correct if I should say that Morse had an electric telephone in his possession in 1850, but was not aware of it.

Cross-Int. 111. In your one hundred and sixth answer you say that under certain circumstances "an iron armature might be employed." I wish you would point out in the book you have referred to which piece is the armature, if there is any there.

Ans. I said that the coil of wire in that particular instrument had a double function, namely, both coil and armature, which function it could not possess if it were made a fixture upon the magnet. In the latter case an extra piece would need to be provided to effect the same end. In other words, a *movable* coil is a well-known substitute for an armature in initiating electric currents.

Cross-Int. 112. The transmitter of Gauss and Weber is described in the passage referred to by you as consisting of permanent magnets, weighing about seventy-five pounds, surrounded by a coil which has seven thousand convolutions, and is provided with handles by which the operator is to lift it up and down.

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Cross-Int. 112. The transmitter of Gauss and Weber is described in the passage referred to by you as consisting of permanent magnets, weighing about seventy-five pounds, surrounded by a coil which has seven thousand convolutions, and is provided with handles by which the operator is to lift it up and down.

If you know of any respectable writer who calls such a device an electro-magnet and armature, I wish you would point out the passage.

Ans. I have just said, myself, that such a device, as is pictured, whatever may be its size and the weight of the movable parts, is properly a magnet in which the coil possesses the function of an armature, *because* it is made movable.

I may be, or may not be, respectable authority for the statement. I nevertheless make it, but would say here that the chief interest that this Gauss and Weber transmitter has is in its being a magneto-electric device by means of which undulatory and vibratory currents of electricity were set up, as distinguished from the intermittent ones which have been so long in use for telegraphic purposes.

Cross-Int. 113. Do you seriously think that your ninth question and answer were calculated to convey to the court or to the mind of any electrician a true notion of the structure of the Gauss and Weber device as it has now been described?

Ans. In my ninth answer I did not attempt a description of that apparatus, nor to tell what it was made to do. I was concerned only with the mechanical, magnetic and electrical relations which are indicated in the drawings of the instrument. I did not understand the question to refer to anything but such mechanical, magnetic and electrical relations as were to be found in that instrument.

The device shows the same magnetic and electrical relations and interchanges of energy when operated as are at present involved in magneto-electric machines of all sorts, including the magnet telephone. It is not intended to be implied that the Gauss and Weber transmitter is a good transmitting telephone, but when it does operate in its own way it produces currents which coincide in their successive changes with the successive changes which are made to take place in mechanical movements in the field of the magnet; that it true.

Cross-Int. 114. The ninth question asks you concerning apparatus which had an "electro-magnet and armature" at each end of the line. Is your idea of the proper use of language such that the Gauss and Weber device can be cited as such an apparatus?

Ans. My opinion is that it would not be difficult to make that Gauss and Weber apparatus transmit speech audibly, and that if it should be done the Bell patentees would claim it as an infringement. The only changes that would be necessary in such an apparatus would be to reduce their size, so that the energy of air vibrations would be sufficient to move the coil, which they would not do to a sufficient extent if the coil weighed many pounds.

[*Answer objected to as not responsive.*]

[*Witness adds:*] As for appropriateness of language, I do not think my language to be inappropriate, and I do not think would mislead an electrician, though the term " electro-magnet " is most generally applied to an iron core surrounded by a coil rather than to a permanently magnetized steel core, but there are all grades and combinations of these.

[*The complainants' counsel here requests the examiner to copy into the record the description of the Gauss and Weber apparatus referred to, which he does. The description is as follows: —*

" *Schilling's proposed plan of giving telegraphic signals with a single needle was carried out in a more complete form by Gauss and Weber, of Göttingen, in* 1833. *Their apparatus consisted of a single magnetic needle, inclosed in a coil of wire, the currents being produced by a magneto-electric inductor. The latter is shown in Fig.* 218. *A hollow column or standard A incloses three straight permanent magnets B, each weighing some twenty-five pounds, and having their similar poles placed in the same direction. A wooden bobbin E E, provided with handles F F', and having* 7,000 *convolutions of insulated copper wire wound upon it, rests upon the top of the column A, and surrounds the magnets B, so that on lifting the bobbin by the handles a current would be induced in the coil in one direction; and on lowering it again a current would traverse the coil in the opposite direction. The wires g g' were connected to a commutator, by means of which they communicated with the line wires.*

" *The receiving instrument is shown in Fig.* 219. *It consists of a large coil or multiplier H H of insulated copper wire, the ends of which are attached at g g' to the line wires. A permanent steel magnet M M, eighteen inches in length, is suspended within the multiplier by a number of silk fibres from the ceiling of the room. A mirror N is attached to the spindle K of the magnet, in which can be observed through a telescope R, at a distance of ten or twelve feet, the* *reflected image of a horizontal divided scale m m. By raising and lowering the inductor at the transmitting station, the magnetic bar at the receiving station is deflected to the right or left, as the case may be. An alphabet was arranged consisting of combinations of right and left deflections, with a maximum of four elementary signals in each letter. It was only necessary that the magnet should have a very slight deflection, as the movements were greatly multiplied by the action of the mirrors and the telescope. It is this apparatus which forms the basis of the reflecting galvanometer now used in cable telegraphy.*"]

[*Noon recess.*]

Cross-Int. 115. In your twenty-third, twenty-fourth and twenty-fifth answers you spoke of what was referred to as the "Wright method," in which sound-waves were used to utilize magnetic strength, etc., and you referred to Ferguson's book on electricity. Did you mean to be understood in those answers as saying that the discharge of the condensers of Dr. Wright in which the sound-waves were utilized was a disruptive discharge?

Ans. I understand that when condensers such as Dr. Wright employed are charged and discharged as there stated so as to produce a sound loud enough to be heard in a large hall, that such sounds are produced by a disruptive discharge, for two reasons. *First*, by experimenting with a similar device myself, I found that there was a disruptive discharge when such loud sounds were produced. And *secondly*, that the device itself is but a well-known arrangement for discharging condensers for the sake of producing a sound. I refer to the experiment of coupling a condenser like a Leyden jar to the terminals of a secondary coil in such a way as to charge the condenser and permit its discharge by means of a jumping spark which is always very much shortened, and the loudness of the sound very much increased as to become deafening if made to take place automatically fifty or a hundred times a second. I therefore think that when such condenser was producing such sound it was due to disruptive action chiefly.

Cross-Int. 116. Is it your notion that disruptive discharge took place inside the condenser, or by a jumping spark outside, as in the experiment you have referred to as well known?

Ans. The discharge in any case is the discharge between the metallic coatings of the condenser, and in the well-known experiment I cited, it is not essential that the discharge shall take place external to the condenser, though it is generally most convenient to so arrange it. When that could not take place, the spark would go between the metallic parts of the paper condenser, and might or might not perforate the paper visibly.

Cross-Int. 117. Since you refer to that experiment as well known, I wish you would point out any passage in any book which states that the discharge by a jumping spark in that experiment takes place inside the condenser.

Ans. I am not now able to recall to mind any particular statement concerning that, but I have for nine years had a Leyden jar in my possession which by an overcharge became perforated, making a hole through the glass between the coatings. That jar gives discharges under such conditions between the coatings with slight sounds.

Cross-Int. 118. Upon page 388 of this deposition you have spoken of " microphonic contact " as a contrivance which operates to vary the current by varying the resistance. When did you first know that such a contact when acted upon by sound-waves could transmit speech if coupled with a suitable receiver?

Ans. The first successful experiments made by myself with such microphonic contact was some time in the latter half of 1877, and I exhibited at the Institute of Technology in the winter of 1877–78 a device embodying that, and in December, 1877, I transmitted speech from Boston to New York with such a device, but the words "microphone" and " microphonic " and " microphonic contacts " were introduced early in 1878 by Hughes to express the proper conditions as he imagined them to be for rapidly varying the strength of an electric current. But on inspection of the conditions present in what are called " microphonic contacts," it is seen that they do not differ materially from such contacts as Reis adopted for telephonic purpose in 1861. The term is now commonly applied to all conducting electric contacts susceptible of delicate movement without rupturing the current, whether such contacts are of metal proper or carbon.

Cross-Int. 119. In your forty-ninth answer you spoke of some experiments in which you had transmitted speech, employing various instruments that were put in evidence in the course of your answer. Please describe how you used each one of those instruments, and what other instruments or accessories you used with each.

Ans. I have used all the instruments in all the ways that I could think of in which the conditions were varied, from a simple circuit consisting of Reis' transmitter and his receiver and battery, through all of the combinations in magneto-receivers, with induction coils, with carbon transmitters of various sorts.

Cross-Int. 120. On page 380 of your deposition you stated that with the instrument *defendants' Reis Exhibit Transmitter* used as transmitter, you have repeatedly heard " whole sentences of spoken words." Will you please state what battery or batteries and what receiver or receivers you had connected with it and listened at when you heard and understood " whole sentences of spoken words " transmitted by means of the apparatus of which this instrument formed the transmitting member?

Ans. I have heard it perform tolerably well with a single cell of a bichromate battery or Grove cell, but better when two or three such cells were used instead of one, and for a receiver the ordinary Reis receiver of the knitting-needle pattern as well as the one marked Reis-Legat; but when I wished to give the instrument the best opportunity to show what it could do in the way of producing an undulatory current, I have coupled it in the primary circuit of an induction coil, and listened at a receiver either of the magneto or my own kind.

Cross-Int. 121. In your last answer have you referred entirely and exclusively to experiments in which you used no transmitter except the identical instrument now on the table before you, and marked " Defendants' Exhibit Reis Transmitter " ?

Ans. In my last answer, I referred in general to experiments which I have made with Reis transmitters, several of which I have had in my possession. I have never had one that I could not thus use as a transmitter of spoken words, and this identical instrument I have often employed in that way, and was able to transmit spoken words and sentences that could be identified by anybody.

Cross-Int. 122. What do you mean by " identified by anybody " ?

Ans. I mean that they could recognize such spoken words when they had no knowledge otherwise of what was spoken at the transmitter.

Cross-Int. 123. Have you ever taken part in the transmission and understood while listening at the receiver, without other knowledge, whole sentences by means of an apparatus of which the Exhibit Reis Transmitter, now on the table before you, formed the transmitting member?

Ans. I have very often both, at that particular transmitter, transmitting words and sentences which I know were heard by the one at the receiver; and I have been at the receiving end when this particular instrument was at the transmitting end, and others spoke there, and I have identified their words.

Cross-Int. 124. Have you while listening at the receiver connected with this identical transmitter heard and understood whole sentences spoken into this transmitter?

Ans. I have heard a very great number of whole sentences, and feel confident of my ability to reproduce speech again with that identical instrument.

Cross-Int. 125. At what receiver did you listen when you heard whole sentences transmitted through an apparatus of which this identical transmitter formed the transmitting member?

Ans. I have heard such words and sentences when the receiver employed was the original Reis receiver, but always much better when magneto-receiver was employed. With the latter there is never any difficulty at all.

Cross-Int. 126. Will you please produce the instrument which you refer to as the Reis receiver in your last answer?

Ans. It is the defendants' Exhibit Reis Receiver.

Cross-Int. 127. Do you mean, then, that with the Exhibit Reis Transmitter now on the table, and Exhibit Reis Receiver now on the table, coupled together with a battery and nothing else in the circuit, you have, while listening at such receiver, heard whole sentences which were spoken into such transmitter and transmitted electrically by means of this apparatus?

Ans. I do.

Cross-Int. 128. What battery did you use on that occasion?

Ans. Two or three Grove cells or their equivalents.

Cross-Int. 129. What was the distance from this transmitting instrument to this receiving instrument when whole sentences were so transmitted?

Ans. A distance of fifty or sixty feet,— the distance between two adjacent rooms at Tufts College where the experiments were tried.

Cross-Int. 130. Do you remember any of the sentences that were transmitted through and by means of these two instruments?

Ans. Really, I have not at any time thought of remembering any particular sentences I may have heard, but have heard a very great variety of sentences through these two instruments.

Cross-Int. 131. When did this transmission through these two instruments take place?

Ans. It has been often done with these two instruments within the last year; these two instruments were brought from Germany about a year and a half ago, so I have not had them so long a time as I have had other instruments.

Cross-Int. 132. In transmitting speech, as you say you have done, using this instrument (Reis transmitter) as the transmitting member, and any receiver as the receiver, did the contact point between the pin carried by the right-angled piece and the little platinum disk on the diaphragm act as a microphonic contact, or did it act to interrupt the current a number of times per second that corresponded with the pitch of the voice of the person speaking into it?

Ans. If it had interrupted the current as many times per second as there were fundamental vibrations of the voice producing the vibrations at the point of contact, speech would have been but imperfectly transmitted, and as the speech may be perfectly transmitted, that is, complete and entire, with the modulations and changes, so that one's voice may be recognized, I think it was due to what we call microphonic contact.

Cross-Int. 133. Will you state whether you have taken part in the transmission of whole sentences by means of an apparatus the transmitting member of which was the same as defendants' Exhibit Reis Transmitter, and the receiving member of which was the Reis-Legat receiver.

Ans. I have, and, in general, have found the latter to be a more efficient receiver for loudness than the knitting-needle receiver.

Cross-Int. 134. Why did you not have this Exhibit Reis-Legat Receiver made of the size described by Legat in his article?

Ans. At the time this receiver was made, I do not remember that the dimensions of it were at hand. This particular instrument was not made for this court exhibit, but was made as an experimental piece of apparatus, in order to ascertain what were its possibilities, and it is put in here because I happened to have it already made.

Cross-Int. 135. The exhibit that you have produced is between one half and one third the size of that described by Legat, is it not?

Ans It appears to be when compared with the drawing.

Cross-Int. 136. Please state the length of the electro-magnet in Legat's description, and the length of the electro-magnet in your exhibit.

Ans. The length of the electro-magnet in Legat's description is four and seven eighths inches, while the length of mine is two and one eighth inches.

Cross-Int. 137. In the instrument described by Legat the armature is very narrow, just covering the poles. In your instrument it is five eighths of an inch wide, and is also long enough to project out a little ways beyond the electro-magnet. Why was this difference?

Ans. I have said that the instrument was not planned to a scale at all, but was planned after the scheme which is shown in the Reis-Legat, and with the view to utilize the varying magnetic attractions to their utmost with the knowledge of the common property of such a magnet. The method of employment has not been changed in the slightest degree by changing the size of the parts, but its efficiency is doubtless increased by having the armature larger.

Cross-Int. 138. You published a book about the telephone in the summer of 1877, did you not?

Ans. I did.

Cross-Int. 139. When did you write it and when did you publish it?

Ans. I wrote it in May and June of that year. It was published late in the summer or early in the fall; I don't remember the date of publishing.

Cross-Int. 140. You therein described the Reis telephone in a passage under the head, "Reis's Telephone," which begins on page 103 and ends on page 106, did you not?

Ans. I did; such description being drawn altogether from the description of Reis's telephone as is given in Prescott's book on electricity and the electric telegraph, which book had just been issued, and it served my purpose then.

Cross-Int. 141. In that description this passage occurs with reference to the Reis apparatus: "If one reflects upon the possibilities of such a mechanism, and upon the conditions necessary to produce a sound of any given quality, as that of the voice, or of a musical instrument as described in preceding pages, he will understand that it can produce only pitch." I suppose that you believed that statement to be true when you wrote it, printed and published it, did you not?

Ans. I intended in that to state what seemed to be apparent; but I have since found it to be wrong, and am exceedingly sorry for having permitted myself to state in such a way what was not possible to the apparatus without some experimental knowledge of it, which at that time I did not have.

Cross-Int. 142. It seems to me that in the passage quoted you undertook to state what one would arrive at upon *reflection*, did you not?

Ans. The mistake in that is in confounding break of contact with break of current. What really is the meaning of that that was written, though it is not implied by the words employed, is that if the current were broken in the way supposed in the instrument, speech could not be reproduced by it.

By "broken in the way supposed" I mean what is stated in the following quotation from the same page of my book: "Now when a sound is made in the box the membrane is made to vibrate powerfully. This makes the platinum strip to strike as often upon the platinum finger and as often to bound away from it, thus making and breaking the current the same number of times per second."

It does not follow that every vibration produced by the voice needs to bring about an entire separation of those contact points, and in point of fact it will not do it unless the producing sounds are above a certain maximum strength. Below that such vibrations will only vary the pressure contact between the platinum parts.

Cross-Int. 143. If the apparatus *did* make and break the current as stated in the quotation given in your last answer, would the conclusion stated in your book, "that it can reproduce only pitch and not quality," be true or not?

Ans. It would be true that the pitch due to that number of vibrations per second would be reproduced and not the quality, unless the quality happen to be of precisely the same sort as that which the instrument would reproduce.

Cross-Int. 144. During the last week of December, 1877, you delivered a lecture on the telephone before the Society of Arts in Boston, did you not? In that lecture did you express concerning the Reis telephone substantially the same ideas as are expressed in your book, or did you express the ideas which you express in this deposition as the ideas which you now hold?

Ans. I did give such a lecture about that time. I do not remember the date, nor do I remember the language that I employed, as I have no record of it, and so cannot state now what I said. It was just about that time that I was experimenting with similar conditions, and succeeded within a week of that time in transmitting speech to New York from Boston by means of such a device that was so loudly reproduced as to be heard ten feet from the receiving instrument in New York; that is to say, the words which I spoke here were heard and understood in New York ten feet from the receiver by means of such a device. I was then just beginning to learn of the possibilities of the Reis transmitter.

[*Adjourned.*]

BOSTON, May 31, 1883.

Cross-Int. 145. The Society of Arts referred to in the last question held its meeting at the Institute of Technology, Boston, and your lecture of December, 1877, was delivered there, was it not?

Ans. I delivered a lecture on the subject of "the telephone" before the Society of Arts some time in December, 1877, at the

Institute of Technology. The date I do not remember, and I have no notes of the lecture at all.

Cross-Int. 146. I read you what purports to be an extract of a report of that lecture made by Dr. Kneeland, secretary of that society, and entered in his official records of the society as follows :—

DEC. 27, 1877.

FROM REPORT BY DR. KNEELAND OF LECTURE BY PROF. A. E. DOLBEAR. EXTRACTED FROM SECRETARY'S RECORD SOCIETY OF ARTS.

"There has lately appeared a letter published by Du Moncel, of Paris, which says that a certain man, whose name is not given, pointed out in 1857 a method for reproducing speech, but his method was not worked out at that time. This story comes so late that little dependence can be placed on it.

"In 1861 a German named Reis actually constructed an instrument precisely after the plan mentioned in the before-mentioned letter which was that a membrane stretched over a box or a tube should be made to make and break a voltaic circuit in a manner analogous to the Page automatic break.

"He then described by diagrams the Reis telephone, and experimented with his form of the Reis instrument. This evidently could only transmit pitch, and could give nothing like speech.

"On the day after the meeting he made an additional experiment in which by a slight modification of the Reis telephone he heard with perfect distinctness and a good degree of loudness talking, singing, etc., the modification consisting of simply one drop of water."

Is that report entered on the society's records a substantially correct report of what you said on that subject at that lecture?

Ans. I do not remember the language that I used on that occasion. Some of this that is quoted reads as if I might have said it, and some of it looks very improbable. I have nothing by which to identify the words which I used then.

Cross-Int. 147. Is it, so far as it goes, a correct report of the substance of what you said on the subject of the Reis apparatus? What is your recollection, if you have any, on that subject?

Ans. What is here quoted concerning a letter published by Du Morcel must have been some newspaper scrap that had then just been published and which I now do not recall. It is in consonance with what I then thought and what I now think concerning the possibilities of a make and break current in such a way, namely, that it is not adapted to the transmission of speech.

Cross-Int. 148. In your one hundred and fourty-fourth answer you speak of transmitting speech from Boston to New York so that words spoken into the transmitter in Boston were heard and understood in New York ten feet from the receiver. Will you please describe the apparatus with which you performed that exploit?

Ans. The instrument used as transmitter was an instrument such as is pictured on page 267 in Prescott's book on the "Speaking Telephone," etc., edition of 1879. The battery employed at that time consisted of from one hundred to one hundred and fifty gravity cells, and the receiving instrument consisted of a magneto receiver consisting of three six-inch horseshoe magnets with soft iron poles containing the coils, and with the diaphragm-armature five and a half or six inches in diameter.

Cross-Int. 149. Was the arrangement referred to in your last answer the one described in the paragraph in "Prescott," page 268, which begins "If a strong battery" and ends with "from a fine point"?

Ans. It is the same.

Cross-Int. 150. The description of the Fig. 126, on pages 267 and 268, was prepared by you or was an abstract of a manuscript prepared by you, was it not?

Ans. This paper was an abstract for a larger paper which was to be prepared by me, but which, on account of sickness at the time, I was prevented from writing. It represents in a very incomplete way what I had intended to prepare for the book. At the time this was printed I was sick with diphtheria.

[*Complainants put in evidence from said book a copy of the description of Fig.* 126, *beginning with the words " The electrophone," on page* 267, *and ending with the words " not so loud." The paper is marked " Complainants' Exhibit Dolbear's Description of a Modified Reis Telephone, W. A. C., Sp'l Ex'r."*]

Cross-Int. 151. At the experiment referred to between New York and Boston, where was the transmitter and where was the receiver?

Ans. The transmitter was in the Western Union Telegraph building in Boston, on State Street, and the receiver was in the Western Union building in New York.

Cross-Int. 152. Who was present with you in Boston?

Ans. The night manager at the office, whose name I cannot recall, with some other of their employés, and my wife.

Cross-Int. 153. The affidavit of Edward Davis in this case contains a copy of *The Scientific American* of June 18, 1881, in which is an article entitled "A New System of Telephony. By A. E. Dolbear." Do you know who wrote that article?

Ans. I wrote it. That is, I wrote all that is in the larger print, ending with the words, "I have often heard them talk, and have made many experiments with such receivers."

Cross-Int. 154. Will you please give the diameter of the free part of the membrane in defendants' Exhibit Reis Transmitter?

Ans. The opening is about an inch and three eighths, but I think that the free part of the membrane is about an inch and five eighths.

Cross-Int. 155. Will you tell me the weight of the right-angled hopping piece, and the pressure which it exerts when at rest upon the platinum patch at the centre of the diaphragm.

Ans. The whole piece weighs 1.051 grams = 16.21 grains. The pressure of the upper electrode on the lower when both are at rest is equivalent to that of a weight .55 grams = 8.486 grains.

Cross-Int. 156. Will you please state the dimensions and resistance of the coil of the instrument defendants' Exhibit Reis Receiver No. 1?

Ans. The diameter of the coil appears to be about nine sixteenths of an inch and the length about five and a quarter inches.

The size of the needle is between thirteen and fourteen, Brown & Sharpe gauge, in diameter, and the length eight and three quarters inches. Wire, No. 22 gauge, and I am informed that the resistance is one and four tenths ohms.

[*The complainants put in evidence all of the publications by or about Bourseul and Reis, which are contained in the following list, that have not already been put in evidence by the defendants. The* *publications put in evidence by defendants are numbered on said list as follows:* 1, 4, 5, 6, 7, 8, 9, 10, 11, 19, 20, 21, 22, 23, 24, 25, 26, 30, 31, 35, 37, 38, 41.]

PUBLICATIONS ABOUT BOURSEUL.

1. Didskalia, Sept. 28, 1854, No. 232.
2. DU MONCEL, Exposé des Applications de L'Electricité. Vol. 2, p. 225, edition 1854; vol. 3, p. 110, edition 1856. Article by Reis.
3. DU MONCEL in Comptes Rendus, Nov. 26, 1877.

DR. CLEMENS'S PUBLICATION.

4. Deutches Klinik, Nov. 23, 1863, No. 48, pp. 857-9.

PUBLICATIONS BY AND ABOUT REIS.

1861.

5. Frankfurter Conversationsblatt, Nov. 29, 1861.
6. Jahres Bericht des Physikalischen Vereins zu Frankfurt am Main. Fur das Rechnungsjahr, pp. 57-64. 1860, 1861. Article by REIS. (Published in 1862.)
7. Fortschritte der Physik, in Jahre 1861, pp. 171-73.

1862.

8. Zeitschrift des Deutsch-osterreichischen Telegraphen Vereins. Vol. 9, p. 125. Article by LEGAT.

1863.

9. Deutsche Industrie Zeitung, No. 16, p. 184, April 17, 1863.
10. Deutsche Industrie Zeitung, No. 18, p. 208, May 1, 1863.
11. Deutsche Industrie Zeitung, No. 22, p. 249, May 29, 1863.
12. Polytechnisches Notizblatt, Dr. Bottger, No. 6, p. 81.
13. Frankfurter Conversationsblatt, June 30, 1863 (copy of No. 12).
14. Polytechnisches Journal of Dr. Dingler, Vol. 168, p. 185 (reprint of 12).
15. Polytechnisches Centralblatt, 1863, pp. 857-9 (reprint of 12).
16. Jahresbericht des Physikalischen Vereins zu Frankfurt am Main, fur das Rechnungsjahr, 1862-1863, p. 35.

Cross-Int. 151. At the experiment referred to between New York and Boston, where was the transmitter and where was the receiver?

Ans. The transmitter was in the Western Union Telegraph building in Boston, on State Street, and the receiver was in the Western Union building in New York.

Cross-Int. 152. Who was present with you in Boston?

Ans. The night manager at the office, whose name I cannot recall, with some other of their employés, and my wife.

Cross-Int. 153. The affidavit of Edward Davis in this case contains a copy of *The Scientific American* of June 18, 1881, in which is an article entitled "A New System of Telephony. By A. E. Dolbear." Do you know who wrote that article?

Ans. I wrote it. That is, I wrote all that is in the larger print, ending with the words, "I have often heard them talk, and have made many experiments with such receivers."

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1. Didskalia, Sept. 28, 1854, No. 232.

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11. Deutsche Industrie Zeitung, No. 22, p. 249, May 29, 1863.

12. Polytechnisches Notizblatt, Dr. Bottger, No. 6, p. 81.

13. Frankfurter Conversationsblatt, June 30, 1863 (copy of No. 12).

14. Polytechnisches Journal of Dr. Dingler, Vol. 168, p. 185 (reprint of 12).

15. Polytechnisches Centralblatt, 1863, pp. 857–9 (reprint of 12).

16. Jahresbericht des Physikalischen Vereins zu Frankfurt am Main, fur das Rechnungsjahr, 1862–1863, p. 35.

17. Letter Reis to Ladd, July 13, 1863, printed in Journal of the Society of Telegraphic Engineers, 1883, No. 46.

18. The Newcastle Daily Chronicle and Northern Counties Advertiser, August 29, 1863.

19. Report of the thirty-third meeting of the British Association for the Advancement of Science, in August and September, 1863.

20. Albert & Reis prospectus. Frankfort, August, 1830.

21. Albert & Reis circular. " " "

22. Albert & Reis description. " " "

23. Polytechnisches Journal of Dr. Dingler, vol. 169, p. 23 (reprint of Legat article, No. 8).

24. Polytechnisches Journal of Dr. Dingler, vol. 169, p. 399.

25. Fortschritte der Physik, 1863, p. 96.

26. Die Gartenlaube, No. 51, December, 1863.

1864.

27. Cosmos, vol. 24, pp. 349–352, March 22, 1864.

28. Proceedings of the Literary and Philosophical Society, of Manchester, Nov. 10, 1864.

1865.

29. Koenig's Catalogue des Appareils d'Acoustique, p. 5.

30. Pisko's die Neueren Apparate der Akustik, p. 94.

31. Pisko's die Neueren Apparate der Akustik, p. 241 (reprint of 22).

32. Handbuch der Angewandte Elektricitatslehre, Von Karl Kuhn, pp. 1017–1021.

1866.

33. Hassler's Technical Physics. Vienna, vol. 1, p. 648.

34. Albert's Catalogue.

1867.

35. Electricity, by Robert M. Ferguson, London, 1867, p. 257.

1868.

36. Lehrbuch der Physik und Meteorologie, Von Joh. Muller, 7th ed., vol. 2, pp. 386–389.

1869.

37. The Manufacturer and Builder, May, 1869, vol. 1, p. 129 (Dr. Van der Weyde).

38. The Telegrapher, vol. 5, No. 39 (the same as No. 37).

39. Proceedings Am. Association for the Advancement of Science, August, 1869 (Dr VAN DER WEYDE).

40. The Boston Daily Advertiser, August 25, 1869 (Dr. VAN DER WEYDE).

41. The Wonders of Electricity, by J. BAILE (*Abbe L'Aborde's tuned-reed circuit-breakers and musical telegraph*).

1873.

42. ALBERT'S Catalogue.

1876.

43. The Scientific American, March 4, 1876 (Dr. VAN DER WEYDE).

44. German report on the exhibition of scientific apparatus in South Kensington Museum, London, 1876, p. 188 (*Reis Telephone*).

1877.

45. Report of the forty-seventh meeting of the British Association for the Advancement of Science, held in August, 1877, published 1878. *On the telephone*, by W. H. PREECE.

46. GANOT'S Elementary Treatise on Physics, eighth edition, translated by E. Atkinson, p. 757.

[*Complainants put in evidence U. S. patent No.* 78,495, *granted to Cromwell Fleetwood Varley, dated June* 2, 1868, *for improvement in telegraphing, marked " Complainants' Exhibit Varley's U. S. Patent of* 1868, *W. A. C., Special Examiner*."]

Cross-Int. 157. In your cross-answers 124–131, inclusive, you refer to the transmission of sentences through and by an apparatus consisting of defendants' Exhibit Reis Transmitter, and defendants' Exhibit Reis Receiver connected in an electrical circuit, with nothing else in the circuit except a battery. Will you, this afternoon, or at some other convenient time, repeat that experiment in the presence of some witnesses whom the complainants may invite to attend?

Ans. I will, at two o'clock this afternoon.

[*Noon recess.*]

The experiments referred to in ths last question and answer are now made. Defendants' Exhibit Reis Transmitter is arranged in one of Mr. Maynadier's rooms, and the Exhibit Reis Receiver in another. The two stations are separated by two intervening rooms, the intermediate doors being closed. Present in the transmitting room, Mr. Buck, who made the connections, and who handled, operated and spoke into the instrument; Mr. Maynadier, Mr. Storrow, Prof. Cross on behalf of complainants, and Mr. Yerrinton, a short-hand writer who took notes of what was said.

In the receiving room Prof. Dolbear, who listened at defendants' Exhibit Reis Receiver, Mr. Chauncy Smith, of counsel for complainants, and the examiner, who made notes. There was also arranged between the two stations an entirely independent circuit with an ordinary magneto telephone at each end, and called the tell-tale line, merely for convenience of communication between the two rooms. Mr. Chauncy Smith attended to the end of this line in the receiving room, and Mr. Storrow in the transmitting room. The experiment began at 2.45 P. M. and ended about 3.15.

The notes of Mr. Yerrinton in the transmitting room are as follows: —

NOTES BY MR. YERRINTON.

In the transmitting room, defendants' Exhibit *Reis Transmitter*, connected through two large Grenet cells, in direct circuit with the receiver, with a key in the circuit which leaves the battery open when not speaking. In the receiving room the defendants' Exhibit *Reis Receiver*, *No.* 1. Prof. Dolbear listening. Tell-tale line, with a hand magneto at each end, also connects the two rooms. Time, 2.45 P. M.

H. C. Buck at transmitter (speaking into top of instrument): Halloa! one, two, three, four, five. Do you get that? One, two, three, four, five — one, two, three. How do you get that? To be or not to be, that is the question. One, two, three, four, five — one, two, three, four, five, six, seven, eight, nine, ten. How do you get that?

(Speaking into mouthpiece): One, two, three, four, five — one two, three, four, five — one, two, three, four, five. How do you get that? Mary had a little lamb, its fleece was white as snow, and everywhere that Mary went, that lamb was sure to go. To be or not to be, that is the question. One, two, three, four, five — one, two, three, four, five — one, two, three, four, five — one, two, three, four, five, six. How do you get that? One, two, three, four, five, six, seven, eight, nine, ten — one, two, three, four, five, six, seven, eight, nine, ten — one, two, three, four, five, six, seven, eight. How do you get that? Mary had a little lamb, its fleece was white as snow, and everywhere that Mary went, that lamb was sure to go. One, two, three, four, five — one, two, three, four, five — one, two, three, four, five. How do you get that? One, two, three, four, five, six, seven, eight, nine, ten. There was a little girl, and she had a little curl, right in the middle of her forehead; and when she was good, she was very, very good, but when she was bad she was horrid. One, two, three, four, five — one, two, three, four, five. How do you get that? To be or not to be, that is the question. Green clouds in air suspended. Steamers arrived in Boston, May 30. New York, Cincinnati, Glasgow, London. How do you get that? One, two, three, four, five, six, seven, eight, nine, ten.

[Mr. MAYNADIER (to Mr. Storrow at the tell-tale line): Won't you ask Mr. Smith [who is in the receiving room] whether Prof. Dolbear has heard anything through there or not? We want to know what the result is there.

Mr. STORROW (through the tell-tale line to Mr. Smith): Halloa! What have you heard? Mr. Smith answers that they have heard some counting, and "How did you get that? How did you get that?" (To Mr. Buck): Stop a little between each sentence, — not so fast. Suppose you speak your sentences into the mouthpiece, not against the top. Take anything out of the newspaper. Don't take common, familiar sentences. Anybody operating a telephone can guess those.]

Mr. BUCK (speaking into the mouthpiece): The royal march and Bavarian hymn announced the arrival of the royal family. The royal hymn announced the arrival of the royal family. The royal hymn announced the arrival of the royal family. How do you get that? One, two, three, four, five. The prince looked very handsome in his costume of blue velvet satin. A, B, C, D, E, F, G. How do you get that? The Bavarian national air. Carts were into service on the New York side as they arrived, and the dead and injured were hurriedly driven out to the City Hall, where they were laid in the police station in the basement. Latest ship news. Halifax, May 30, 1883. It was not found. It was said that a man had been seen carrying a dead baby away, but the police had no account of it.

[Mr. Storrow (through the tell-tale line to Mr. Smith): Halloa! Yes, we have been talking away for five minutes. Wait a moment. What? We have just lifted the plates out a moment to rest the battery. Now listen.]

Mr. Buck (into the Reis transmitter): Reports are still coming in of the effects of the storm on Monday. At Freeport the bridge across the river was torn from its piers. One, two, three, four, five, six, seven, eight, nine, ten. How do you get that? One, two, three, four, five. Clothing was scattered about in every direction. More than half a score were dead when extricated from the throbbing heap. How do you get that? Others were more or less terribly injured. They lay eight or ten deep, those in the lower tier long dead. All were hatless, many shoeless, and on others the clothes hung in rags. Five women, all dead and trampled into an unshapely mass, were taken from the bottom of the heap. One, two, three, four, five. Mary had a little lamb. A, B, C, D, E, F, G. To be or not to be, that is the question. One, two, three, four, five, six, seven, eight, nine, ten. How do you get that (six whistles)?

(Speaking in top of instrument): One, two, three, four, five — one, two, three, four, five.

[Mr. Buck: Do you want me to go on any longer?

Mr. Storrow: Wait a moment, until I go into the other room.

(Mr. Storrow and Prof. Cross left the room, but soon returned.)

Mr. Maynadier: There is something the matter with the wire; I reckon that is the trouble.]

Mr. Buck (*speaking into the mouthpiece*): By three o'clock the crowd in the pleasant grounds surrounding the Hotel Pines numbered nearly 10,000 people. (Speaking to the top): By three o'clock the people in the grounds numbered nearly 10,000. (Speaking into mouthpiece): Many sat on the broad piazzas. (Speaking to the top): Many sat on the broad piazzas. The clear skies promised a fair day. (Speaking in the mouthpiece): The clear skies promised a fair day. (Speaking in the top): The clear skies promised a fair day. (Speaking in the mouthpiece): Rome, Italy, May 17, 1883. (Speaking in the top): Rome, Italy, May 17, 1883. One, two, three, four, five. (Speaking in the mouthpiece): Some of these entertainments were poor and unsuccessful; others superb, and only in Rome could they have occurred. (Speaking in the top): Only in Rome could they have occurred. (Speaking in the mouthpiece): Showery, gusty weather destroyed the effect of the gala entry, illuminations, the curious characteristic art celebration, etc. Destructive fire at Lynchburg, Va. Five persons killed. The property loss $300,000. (Speaking in the top): Five persons killed. (Speaking in the mouthpiece): Lynchburg, Va., May 30, 1883. The most disastrous fire that ever swept over this city broke out at ten o'clock this morning. (Speaking in the top): The *Daily Virginian* building and fixtures, the Commercial Bank, the large hardware establishment of John Watts, Brothers & Co. Berlin May 30, 1883. The workman's sick fund bill passed its third rea in the Reichstag to-day. (Speaking in the mouthpiece): In the use of Commons this afternoon the bill empowering the local auth ities in Ireland (speaking in the top) to improve the dwellings of laborers passed its third reading. One, two, three, four, five, six, seven, eight, nine, ten. (Speaking in the mouthpiece): From our Rome correspondent. Fêtes in honor of the Duke of Genoa and his bride. (Speaking in the top): Fêtes in honor of the Duke of Genoa and his bride.

[Mr. **Buck**: I don't believe it is any use to continue on in this strain.

Mr. **Maynadier**: Something is the matter, I should think. Either the connections are wrong —

Mr. **Storrow**: The connections seem to be all right.

Mr. **Maynadier**: I think you ought to try some other way.

Mr. **Storrow**: I don't care for anything more, unless you do.

Mr. **Buck** (to Prof. Cross): Would you like to speak here?

Prof. **Cross**: I was just going to ask you to send through some irregular numbers, instead of sending through regular numbers. Leave long enough space between them, so he can repeat.]

Mr. **Buck** (speaking in the mouthpiece): 5—5—3—8—8—10 1—2—10—4—6—40—32—25—99—32—25—86—55—101—302 508—603—904—201—325—486.

[Mr. **Storrow**: Halloa! I am going to ask Mr. Buck to sound a note, expecting it will break the circuit. Please listen and see what pitches you get. Halloa! What is it? Ask Mr. Dolbear to listen carefully now, and note the different pitches that he hears. (To Mr. Buck): Speak loud enough to break the circuit, intending to break the circuit.]

Mr. **Buck**: Do—mi—sol—do—do.

[Mr. **Storrow**: Halloa! Did you notice any difference of pitch then? Mr. Smith answers through tell-tale line that they were not listening.]

Mr. **Buck**: Do—mi—sol—do—fa—mi—do.

[Mr. **Storrow** (to Mr. Smith through the tell-tale line): What did you hear then? Answer through tell-tale line. Mr. Dolbear says he hears sounds of a different pitch. (Mr. Storrow through tell-tale line): Now listen again, please. Do it over again, please, Mr. Buck.]

Mr. **Buck**: Do—mi—sol—do—sol—mi—do.

[Mr. **Storrow**: What did you hear then? He answers through tell-tale line that he again heard sounds of a different pitch. Mr. Maynadier, do you want to try anything more?

Mr. **Maynadier**: No.]

THE NOTES OF MR. COPELAND IN THE RECEIVING ROOM ARE AS FOLLOWS: —

First trial: —

Prof. Dolbear says: I heard him say, "One, two, three, four, five, six, seven."

I also heard him say, "How do you get that?"

Some of the numbers I did not hear. I only inferred.

I heard him say, "One, two, three, four, five."

I heard him say, "That."

I heard him count the whole ten, plain.

I heard him count five very plain, in a low tone of voice.

I heard him say, "How do you get that," after counting five.

[Mr. Smith says into the tell-tale line that Prof. Dolbear heard counting and "How do you get that?"

Prof. Dolbear says: "I thought he said, one, two, three, forty. I don't hear anything now but a make and break."

[During the experiment Prof. Dolbear pressed the instrument close to one ear and closed the other.]

Another trial. [3.05 o'clock.] Prof. Dolbear says: —

I heard him say, "One, two, three, four, five," easy.

I heard him say, "One, two, three, four, five, six, seven."

I heard him say, "Mary had a little lamb."

I heard him say, "Mary had a little."

I heard him say, "Mary had a little lamb" again.

I heard him say so again.

They are not transmitting anything.

[3.12.] Six minutes since starting this trial.

Another trial. [3.15.]

I hear sounds of different pitch.

I hear sounds of different pitch when it is at my ear, but which sounds have but little difference of pitch at some little distance from the ear.

[*Adjourned to Friday, June* 1.]

BOSTON, June 1, 1883.

[*From the book already referred to, published in the fall of* 1877, *called* "*The Telephone,*" *by Prof. A. E. Dolbear, the complainants put in evidence the two consecutive passages, entitled* "*Bell's Telephone,*" *and* "*First Form of Speaking Telephone,*" *beginning on page* 110, *and ending on page* 116, *and marked* "*Complainants' Exhibit Second Extract from Dolbear's Book, W. A. C., Special Examiner.*"]

Redirect Examination.

Int. 158. As to the experiments yesterday afternoon with the Reis transmitter and the Reis receiver, state whether you in fact received any word, words, or sentences from the receiver, and how the working of the apparatus compared with its working on other occasions.

Ans. I did receive several words and sentences fairly well, but I have on several former occasions heard much better than yesterday afternoon. The room was not so quiet as the room should be when the sounds are weak and scattered as much as they necessarily are i so poor a form of receiver as is the Reis knitting-needle receiver. I have never been able to hear continuously with such an arrangement, but occasionally have heard words and short sentences, when the latter were quite unexpected, and this on several occasions while testing to discover the capacity of the instrument.

Int. 159. Was the fault, yesterday, mainly with the receiver or with the transmitter?

Ans. I think the fault to have been chiefly due to the receiver, which is badly cracked, and in a worse condition than it had ever before been when I tested it.

The irregular crack, "1, 2, 3, 4," was not in the instrument the other day when it was put in evidence. The long crack marked "5, 6, 7," was there when put in evidence. The crack marked "8, 9," I am sure was also made since it was brought here, as also "10, 11, 12," the longitudinal crack along the front edge. All of these are in the bottom sounding board. The cracks in the top sounding board, I think, are all old, but am not sure as to one of them.

Int. 160. Did you test the Exhibit Reis Transmitter yesterday afternoon, after the experiments in the presence of complainants' counsel were over? If so, how did you test it and with what results?

Ans. I did test that transmitter by putting it in a primary circuit of an induction coil, and listened with a magneto receiver in the secondary. I was able to hear nearly every word that was said.

Int. 161. And what is the inevitable conclusion as to the current in the primary, of which Exhibit Reis Transmitter formed a part, and as to whether the Reis Transmitter operated according to the theory set forth in most, if not all, of the publications about Reis, or in accordance with the more modern theory?

Ans. There is but one conclusion that can possibly be drawn from the experiment, when the Reis transmitter is employed for the purpose of transmitting speech, and speech is transmitted and heard with any kind of a receiver, and that is that the Reis transmitter can and does produce the appropriate undulatory currents by virtue of the movements of its parts, and is in itself a demonstration that the old theory of a necessary make and break of current during vibration is wrong, and that the more modern theory of the action of the instrument is correct.

Int. 162. Prof. Cross implies in his affidavit, as I understand him, that there is no difference, in substance, between the apparatus described by Dr. Van der Weyde in the *Manufacturer and Builder*, so far as concerns the transmitter, and the Exhibit Reis Transmitter, and such others as Reis made and caused to be made, and sold about 1863, and afterwards. Please state how the fact is. I refer to the page 38 of Cross's first affidavit.

Ans. In this device of Van der Weyde, as described in the *Manufacturer and Builder*, one of the electrodes was made a fixture to be adjusted by means of a screw, which arrangement allowed the whole of the movement to be performed by the membrane, and thus admit of makes and breaks of current in a different way from that provided by Reis, who so arranged the electrodes that both were movable. In Van der Weyde's transmitter the arrangement was perhaps the best that could be devised, if the intention was to break the current for every vibration, and when the instrument was quiescent there was no contact between those electrodes. He says that the screw should "be so adjusted as to come very nearly in contact with this small platinum disk." Thus the arrangement as he planned was unlike Reis's, for the latter had a constant contact when the instrument was not in service as a transmitter.

Int. 163. You say simply "unlike." Please explain what sort of unlikeness you mean; for example, whether it is possible under any conditions to transmit speech with the Reis transmitter altered and adjusted as described by Van der Weyde, and whether the true Reis transmitter is or is not an efficient instrument precisely the same in kind as what is now called the microphone transmitter, and certain in all cases to operate well where the other conditions are what they should be?

[*Objected to as immaterial, and as calling upon the witness to contradict the publications put in evidence by the defendants.*]

Ans. With the Reis transmitter altered as described by Dr. Van der Weyde, in which there is a special provision made for an interruption in the current, it is not possible to transmit speech; and Dr. Van der Weyde himself recognized that, and declared that ar so poor a form of receiver as is the Reis knitting-needle receiver. I have never been able to hear continuously with such an arrangement; but occasionally have heard words and short sentences, when the latter were quite unexpected, and this on several occasions while testing to discover the capacity of the instrument.

Int. 159. Was the fault, yesterday, mainly with the receiver or with the transmitter?

Ans. I think the fault to have been chiefly due to the receiver, which is badly cracked, and in a worse condition than it had ever before been when I tested it.

The irregular crack, "1, 2, 3, 4," was not in the instrument the other day when it was put in evidence. The long crack marked "5, 6, 7," was there when put in evidence. The crack marked "8, 9," I am sure was also made since it was brought here, as also "10, 11, 12," the longitudinal crack along the front edge. All of these are in the bottom sounding board. The cracks in the top sounding board, I think, are all old, but am not sure as to one of them.

Int. 160. Did you test the Exhibit Reis Transmitter yesterday afternoon, after the experiments in the presence of complainants' counsel were over? If so, how did you test it and with what results?

Ans. I did test that transmitter by putting it in a primary circuit of an induction coil, and listened with a magneto receiver in the secondary. I was able to hear nearly every word that was said.

Int. 161. And what is the inevitable conclusion as to the current in the primary, of which Exhibit Reis Transmitter formed a part, and as to whether the Reis Transmitter operated according to the theory set forth in most, if not all, of the publications about Reis, or in accordance with the more modern theory?

Ans. There is but one conclusion that can possibly be drawn from the experiment, when the Reis transmitter is employed for the purpose of transmitting speech, and speech is transmitted and heard with any kind of a receiver, and that is that the Reis transmitter can and does produce the appropriate undulatory currents by virtue of the movements of its parts, and is in itself a demonstration that the old theory of a necessary make and break of current during vibration is wrong, and that the more modern theory of the action of the instrument is correct.

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Int. 163. You say simply "unlike." Please explain what sort of unlikeness you mean; for example, whether it is possible under any conditions to transmit speech with the Reis transmitter altered and adjusted as described by Van der Weyde, and whether the true Reis transmitter is or is not an efficient instrument precisely the same in kind as what is now called the microphone transmitter, and certain in all cases to operate well where the other conditions are what they should be?

[*Objected to as immaterial, and as calling upon the witness to contradict the publications put in evidence by the defendants.*]

Ans. With the Reis transmitter altered as described by Dr. Van der Weyde, in which there is a special provision made for an interruption in the current, it is not possible to transmit speech; and Dr. Van der Weyde himself recognized that, and declared that ar ulate words could not be sent by it, because there were such interruptions in the current. This was saying in a negative way that unbroken, undulatory currents were necessary for the transmission of speech. On the other hand, in the Reis transmitter there is provision for a continuous current, the strength of which is to be varied by the pressure of the movement of the electrodes, a condition which is precisely the same as is found in all instruments now known as "microphones," so far as contacts and freedom of motion are concerned.

Int. 164. All of your cross examination up to Cross-Int. 72, inclusive, relates to the charge or the electrification of the plates of your receiver. What, if anything, is there in the Bell method or in the Bell apparatus, or in either of the Bell patents in suit, in any way resembling this, or conveying any information or hint, however vague, as to this?

Ans. There is nothing whatever in either of those patents concerning any such electrical conditions, nor any hint that such use of electricity was possible, nor any apparatus referred to in which it is possible to utilize an electric charge for the purpose of the transmission of speech or for any other purpose.

Int. 165. How does the charge or electrification of the secondary coil and transferrer compare with that of the metallic part of the plate connected with the transferrer; and what was the state of the art as to this before your discovery?

Ans. The potential of the plate in connection with the transferring wire becomes practically the same as that at the terminal of the coil in connection with the same wire; that is to say, the whole transferring wire and plate acquire the same potential as that end of the coil with which they are connected, a condition which is not possible to have when conduction is permitted by means of a conducting wire to ground.

This physical condition of insulated metallic conductors has been known for a long time, but until I discovered the present method of utilizing it I do not know of any practical application of an electric charge.

Int. 166. Please compare the effect of a given magnetic change in the transmitting core of the apparatus for transmitting speech shown in the Bell patents in suit, with the effect of the same magnetic change in the transmitting core of your apparatus.

Ans. In the telephones described in the Bell patents of 1876 and 1877 the movement of the armatures of the magnet induces an electro-motive force in the coils, which electro motive force is exceedingly weak, as shown by the weakness of the sounds in the receiver, such electro-motive force giving rise to currents whose strength is so small, as computed by Prof. Tait and others, as to make it a surprise that they are capable of making themselves heard at all. With my device the magnetic changes which give rise to electro-motive force in the coil are many hundreds of times and perhaps thousands of times greater, and of course it has capabilities which the other cannot approach.

In the case of a *given* magnetic change in the core in the two instruments, the electro-motive force developed will depend upon two conditions: —

First. The number of turns of wire in the coil upon which the magnetic core reacts.

Second. Upon the resistance in the external circuit. The greater the number of turns in the helix, the higher will be the electro-motive force; and the greater the external resistance, the higher the electro-motive force.

With small coil and small external resistance, as in the instruments shown in the Bell patents, the electro-motive force developed must be relatively low for both reasons, as it is impossible that a coil should develop its maximum electro-motive force so long as a conducting circuit is provided.

The same magnetic change would, with my coil, my line and my receiver produce the maximum electro-motive force, charging the whole line with the receiving plate, thus enabling one to utilize the maximum electro-motive force.

The difference in these two conditions is very great. There is great difficulty in measuring with accuracy the difference in the electro-motive force in these two cases so as to state it numerically, but the difference in the two cases may be in my opinion as great as a hundred or even a thousand times.

[*Noon recess.*]

ulate words could not be sent by it, because there were such interruptions in the current. This was saying in a negative way that unbroken, undulatory currents were necessary for the transmission of speech. On the other hand, in the Reis transmitter there is provision for a continuous current, the strength of which is to be varied by the pressure of the movement of the electrodes, a condition which is precisely the same as is found in all instruments now known as "microphones," so far as contacts and freedom of motion are concerned.

Int. 164. All of your cross examination up to Cross-Int. 72, inclusive, relates to the charge or the electrification of the plates of your receiver. What, if anything, is there in the Bell method or in the Bell apparatus, or in either of the Bell patents in suit, in any way resembling this, or conveying any information or hint, however vague, as to this?

Ans. There is nothing whatever in either of those patents concerning any such electrical conditions, nor any hint that such use of electricity was possible, nor any apparatus referred to in which it is possible to utilize an electric charge for the purpose of the transmission of speech or for any other purpose.

Int. 165. How does the charge or electrification of the secondary coil and transferrer compare with that of the metallic part of the plate connected with the transferrer; and what was the state of the art as to this before your discovery?

Ans. The potential of the plate in connection with the transferring wire becomes practically the same as that at the terminal of the coil in connection with the same wire; that is to say, the whole transferring wire and plate acquire the same potential as that end of the coil with which they are connected, a condition which is not possible to have when conduction is permitted by means of a conducting wire to ground.

This physical condition of insulated metallic conductors has been known for a long time, but until I discovered the present method of utilizing it I do not know of any practical application of an electric charge.

Int. 166. Please compare the effect of a given magnetic change
the transmitting core of the apparatus for transmitting spe

shown in the Bell patents in suit, with the effect of the same magnetic change in the transmitting core of your apparatus.

Ans. In the telephones described in the Bell patents of 1876 and 1877 the movement of the armatures of the magnet induces an electromotive force in the coils, which electro motive force is exceedingly weak, as shown by the weakness of the sounds in the receiver, such electro-motive force giving rise to currents whose strength is so small, as computed by Prof. Tait and others, as to make it a surprise that they are capable of making themselves heard at all. With my device the magnetic changes which give rise to electro-motive force in the coil are many hundreds of times and perhaps thousands of times greater, and of course it has capabilities which the other cannot approach.

In the case of a *given* magnetic change in the core in the two instruments, the electro-motive force developed will depend upon two conditions: —

First. The number of turns of wire in the coil upon which the magnetic core reacts.

Second. Upon the resistance in the external circuit. The greater the number of turns in the helix, the higher will be the electro-motive force; and the greater the external resistance, the higher the electro-motive force.

With small coil and small external resistance, as in the instruments shown in the Bell patents, the electro-motive force developed must be relatively low for both reasons, as it is impossible that a coil should develop its maximum electro-motive force so long as a conducting circuit is provided.

The same magnetic change would, with my coil, my line and my receiver produce the maximum electro-motive force, charging the whole line with the receiving plate, thus enabling one to utilize the maximum electro-motive force.

The difference in these two conditions is very great. There is great difficulty in measuring with accuracy the difference in the electro-motive force in these two cases so as to state it numerically, but the difference in the two cases may be in my opinion as great as a hundred or even a thousand times.

[*Noon recess.*]

Int. 167. How do the maximum magnetic changes in the transmitting core of the commercial telephone — by which I mean a microphone transmitter in the primary, and a magneto receiver in the secondary of an inductorium — compare with the maximum magnetic changes in the transmitting core of the apparatus described in Bell's patents in suit?

Ans. In the commercial telephone as described, the magnetic changes are much greater than corresponding changes in the transmitting telephone shown in the patents; and the adoption of this arrangement in the transmitter was a step of the highest importance commercially, the electro-motive force at command being much greater than could be produced in the original method as shown in the patents.

Int. 168. How does the effect of the maximum magnetic change in the transmitting core of the commercial telephone compare with the effect of such a magnetic change in the transmitting core of your apparatus?

Ans. In the common commercial transmitter, the secondary coil of which is small, containing but about one hundred and fifty ohms resistance, and with a small core in which magnetic changes may be set up, the electro-motive force when at its maximum for such a coil, which can only be when the terminals of the coil are separated so as to prevent the passage of the current which would otherwise flow, will be very much lessened by closing the circuit, as is done in the ordinary use of the magneto telephone.

With the circuit open with such a coil I found the electro-motive force on a given occasion to be about seventy-five or eighty volts, which would be its maximum under such conditions, but which number would not represent the electro-motive force when the secondry circuit was closed, for reasons already stated.

With my coil having a larger core and a very much larger secondary, a given magnetic change reacting upon the larger secondary would yield a much higher electro-motive force; and as in my method I do not have a closed circuit, and can therefore develop for my use a maximum electro-motive force, which was, according to the measurement I made, about twenty-seven hundred volts. If the two be compared roughly, it is plain that the electro-motive force I employ when operating my method must be forty or fifty times higher than that used in the telephones with magneto receivers.

Int. 169. What is the electro-motive force ordinarily employed in telegraphy and electric lighting and electro-plating?

Ans. In electric telegraphy the electro-motive force varies with the resistance of the line, and for a line, say from Boston to Providence, would generally be about twenty or thirty volts. For electric lighting by arc the electro-motive force would be about fifty volts for each light in the circuit. With electro-plating the electro-motive force is seldom more than one or two volts. By twenty or thirty volts, as applied to the telegraph, I mean the electro-motive force such as twenty or thirty gravity cells would yield, though the actual electro-motive force given by such a battery on a closed circuit would be considerably less than what would be given by the same battery on open circuit if tested.

Int. 170. A vigorous attack has been made upon your ninth answer. Please reconsider that answer in view of that attack, and state what Gauss and Weber added to the stock of knowledge.

Ans. In my ninth answer I had altogether in my mind the mechanism in its electrical relations rather than in its particular parts, and I did not observe that my attention was called to particular parts of the apparatus. What I described was the general conditions for generating and receiving electrical currents, and the character of such currents as generated in that apparatus.

The term "armature," as applied to that apparatus, is a term that is not generally applied to such arrangement, and my use of the term, as applied there, is not a common one, not that it is inexact, but that in ordinary use it is not so applied.

That that Gauss and Weber added was a method of transmitting signals by means of to-and-fro currents, which currents were produced by corresponding to-and-fro movements of the generating coil. At that time that seemed to be a decided advance in the art of telegraphy.

Int. 171. Is the magneto receiver in fact a galvanometer?

Ans. It is a delicate galvanometer for indicating the existence of very slight currents, — one of the most delicate which we possess.

Int. 172. As to the passage from your book showing that the

Reis receiver was not adapted to transmit quality, please explain what you meant and what you then regarded the Reis transmitter to be.

Ans. The description which I then gave of the Reis transmitter was one which I took from other descriptions of the device, and in which I supposed it to be a make and break instrument from necessity, and before I had experimented with it. I was not aware, until some time in the spring of 1878, that Reis had obtained articulate results with his device, and in what I wrote and what I said about that time I was simply reciting the description of Reis, which I had happened to see.

[*Complainants object to the statement that Reis had "obtained articulate results," on the ground that it contradicts the statements contained in the publications put in evidence by the defendants.*]

Cross Examination resumed.

Cross-Int. Where did you ever hear the magneto receiver called a galvanometer, and in what book do you find it called a galvanometer?

Ans. 173. I cannot point out now without reference to my books the specific places where the magneto telephone is called a galvanometer; but I have seen it so called, and know that it has been used when its sole function was to indicate the presence of electrical currents, and as that is one function of a galvanometer, if the magneto telephone be used for that purpose, it is a galvanometer.

Cross-Int. 174. The galvanometer shown by Gauss and Weber, and the instrument technically known as the galvanometer, are instruments which depend for their action upon the disposition of a magnetized needle to place itself at right angles to an electric current, are they not?

Ans. In the Gauss and Weber galvanometer the arrangement was such as described, but in Weber's galvanometer there is not such an arrangement, neither is there in such a galvanometer as I described and patented three or four years ago, in which a core of iron was drawn more or less into a helix through the action of a current of electricity. There are many ways in which currents of electricity react upon each other and upon magnets, any of which may be used to indicate the presence of currents of electricity, and any such arrangement may properly be called a galvanometer when used for such a purpose.

[*All except the first twelve words objected to as not responsive.*]

Cross-Int. 175. In listening at the defendants' Exhibit Reis Receiver yesterday afternoon it was the top or side of the instrument which you applied to your ear chiefly, was it not?

Ans. It was.

Cross-Int. 176. At the present moment and during most of your examination for the last fortnight you have on the table before you, and have had on the table or window sill in this room, another Reis receiver of the needle form, and with a round box of a shape like that you used yesterday, have you not?

Ans. I have.

Cross-Int. 177. Will you please look at the examiner's notes of what you said you heard yesterday afternoon, and state what the sentences were which you referred to in your one hundred and fifty-eighth answer this morning?

Ans. I heard him say, "How do you get that?" twice.

I heard him say, "Mary had a little lamb" three times, and "Mary had a little" once.

Cross-Int. 178. Are you aware of the fact that at the beginning of the trial, when you did *not* hear the words, "Mary had a little lamb," they were spoken into the transmitter several times, and towards the close of the trial, when you thought you heard "Mary had a little lamb" three times and "Mary had a little" once, no such phrases were spoken into the transmitter?

Ans. I was not aware of that.

Redirect.

Int. 179. Do you think the other Reis receiver is in better condition and will give better results with the Reis transmitter than the one marked as an exhibit (Reis Receiver No. 1)?

Ans. It has generally done so when it has been tested, and the only reason for using the other — the Exhibit No. 1 — rather than this, was because the exhibit was made in Germany and was intended to be a *fac-simile* of those made by Reis himself, and as I had often heard words with it I had no doubt of my ability to hear again as well, and the same is to be said of the transmitter, which was also made in Germany. I have had another Reis transmitter which would work twice as well as the present one, but did not have that one now in my possession.

Int. 180. Are you prepared to test the matter with this receiver, Exhibit Reis Receiver No. 2, as you did yesterday afternoon, and also to test both the Reis receivers with some modern transmitter to see whether the receivers are in working order or not, and test the Reis transmitter with some modern receiver?

[*The receiver referred to in cross-int.* 176 *is now put in evidence and marked "Defendants' Exhibit Reis Receiver, No.* 2, *W. A. C., Special Examiner."*]

Ans. I don't want to do any experimental work when I have to have such objectionable conditions imposed upon me as were imposed upon me yesterday afternoon.

[*Defendants' counsel here offers to have the tests made as described in his question by two competent persons if the complainants' counsel so desires, and requests the complainants' counsel to consent to such tests with a view to having it demonstrated, first, that Exhibit Reis Transmitter will work well with any modern magneto receivers; secondly, that both the Reis receivers put in as exhibits will work fairly well with any modern transmitter (unless indeed the recent cracks in one of them may impair its working); and, thirdly, that the Reis transmitter in circuit with Reis receiver No.* 2 *will transmit speech fairly well.*

Complainants' counsel states that it was agreed yesterday afternoon that if the defendants wished to try any more experiments with the Reis apparatus the complainants would attend at 3 *o'clock this afternoon for that purpose, and thereupon the same gentlemen who were present yesterday afternoon did attend for that purpose; that as the defendants' counsel seems to have been under some misapprehension, the complainants will endeavor to attend to-morrow or at the earliest moment for that purpose, but objecting that the experiments, especially those marked " Firstly," and " Secondly," are not material to the case.*]

BOSTON, June 2, 1883.

The experiments took place as follows: —

NOTES OF MR. BARNES, SHORT-HAND WRITER, AT THE TRANSMITTING ROOM.

Transmitting station: Present, Mr. Maynadier, Mr. Storrow, Prof. Cross, Mr. Eaton and Mr. Barnes.

At the receiving station: Mr. Buck at the receiver, Mr. Chauncy Smith, Mr. Copeland and Mr. Leighton.

At the transmitting station: Defendants' Exhibit *Reis Transmitter* connected in circuit with one Grenet cell, and a finger key in the circuit which opens the circuit when not in use.

In the receiving room connected with this is the *magneto receiver No.* 9, Mr. Buck listening at it; also between the two rooms an independent circuit used as a tell-tale line, with a magneto telephone at each end, Mr. Smith attending at the end in the receiving room and Mr. Storrow in the transmitting room.

[MR. STORROW (through tell-tale line): Hullo! hullo! are you ready?]

MR. EATON (speaking against the top of the Reis transmitter and not into the mouthpiece): Hullo! Mr. Buck. Do you get this all right? Mr. Buck, are you all right, Mr. Buck?

[MR. STORROW (through tell-tale line): Hullo! are you ready? Hullo! hullo! are you ready and listening?]

MR. EATON (speaking as before and about a foot away from the transmitter): Hullo! Mr. Buck. One, two, three, four, five. Do you get this all right? [Time 10.52.] A gentleman here says not to go so quick. How do you like it? One, two, three, four, five, six, seven, eight, nine, ten. Mr. Buck, I don't know whether I have got this arranged just right or not, because I can't get any word from you, but I guess you will get some of it all right. How do you like that, Mr. Buck? Boston, Charlestown, twenty-five, eighty-four, one hundred and one, two. Get any of those figures? Hullo, Mr. Buck, did you get any of that? One, two, three, four, five, six, seven, eight, nine, ten. How is that, all right?

[MR. STORROW (tell-tale line): Hullo, what is it? Hullo there, what is it?]

Mr. EATON: Hullo, what is it?

[Mr. STORROW (tell-tale line): Hullo, Mr. Smith. Hullo, hullo.]

Mr. EATON: Hullo, Mr. Buck. Mr. Storrow was hollering to Mr. Smith; didn't any of you get anything there?

[Mr. STORROW (tell-tale line): Hullo. Are you ready, listening? Now we will go ahead.]

Mr. EATON: Mr. Storrow tells me to go ahead, Mr. Buck. Are you listening there? One, two, three, four, five. How do you get that, all right? Am I about the right distance away? Would you rather have me speak down in here than up on top? How do you get this? (This last sentence spoken into the mouthpiece.) Hullo, I understand you want it a little lower. How do you get this, Mr. Buck, all right? Boston, Charlestown, Somerville, seventy-five, eight hundred and twenty, three, sixteen, eighty-five, twenty-four. Get that all right? The defeat which the government suffered in the division on the affirmation bill has set people thinking seriously about their future and that of the present Parliament. It is the first heavy check they have encountered, and our experience is that a ministry which has once been beaten in a pitched battle seldom recovers its strength, and never its prestige. Had this battle been one of a distinctly party character, the ministry must, of course, have resigned. How is that, all right, Mr. Buck? But the bill they were beaten on was no part of their political programme. They did not take the matter up because they regarded it as one of political consequence, but merely in order to extricate the House of Commons and constituency of Northampton from a dead lock which was disquieting to both Parliament and the country, as they contended that the House of Commons had erred in refusing to permit Mr. Bradlaugh to take the oath after his re-election from Northampton. They might, perhaps, have left it to bear or settle for itself the consequences of that error, but there is a general feeling in England that when any screw gets loose it is the business of the executive to put it into its place again, and the fact that the question of Mr. Bradlaugh's admission remained open was damaging to the ministry in both directions. How is that, all right?
Time 10.58.

[Mr. Storrow (tell-tale line): Hullo, hullo. Are you ready? About one minute. Are you ready?]

(The speaking so far has been into the top of the instrument, and not into the mouthpiece, and at a distance of from four inches to a foot from the membrane.)

[Mr. Maynadier: The trouble is, Mr. Buck says, Mr. Smith wanted him to speak every word he heard and Mr. Buck cannot do that, the way you talk so rapidly, without losing, as you see at once, the greater part of what immediately follows, because while he is speaking, saying what he heard, he loses all that immediately follows. He only knew you were talking about Bradlaugh and the English government; something of that sort.]

Mr. Eaton (speaking to top of the instrument. [Time 11.03.] Reading): To the editor of the *Nation*, — Sir: In your issue of May 3, "The real Weakness of American Universities" is discussed from the standpoint of professional emolument without any reference to other, and, as it seems to me, more potent causes for the present low standard of our higher education. The discouraging effects in the end of a poor salary cannot be doubted. Even the most enthusiastic and zealous promoter of any department of science to feel that earnest and continued effort is rewarded through years by only a meagre competence sufficient to keep the wolf from the door.

[Mr. Storrow (tell-tale line): Hullo. Mr. Buck says you speak too strong. Now, listen. We will go ahead.]

Mr. Eaton (reading): Without any possible prospect of being able to provide a small surplus for the contingencies of the future. To see the responsibilities of life grow heavier every day with no hope of meeting them and rising above them by patient, earnest labor, is surely disheartening in the extreme, and yet I apprehend that this is not the worst thing that can happen to a man whose life is devoted to his calling as a professor. This is merely an external source of anuiety, which will cool the ardor and check the enthusiasm.

[Mr. Storrow (tell-tale line): Hullo! What is it? Yes.]

[Time 11.07.]

[Mr. Storrow: Well, what is it? Yes, what is it? Yes. *Mr. Buck has taken off No. 9 receiver, and put on No. 10 receiver.*]

[Mr. Storrow: Hullo! Hullo. Are you ready?]

[Time 11.10.]

Mr. Eaton: Hullo, Mr. Buck! One, two, three, four, five, six, seven, eight, nine, ten.

I understand you have got on a different receiver.

Do you get that all right?

"The dissolution of the Reichstag, which at the opening of this session seemed imminent, will not take place, for Bismarck cannot expect by new elections to get a successor which will help him to carry out his policy effectually. Another cause of inactivity and inefficiency in university training in America is connected with the university system itself. Healthy criticism of one another is almost wholly unknown among its professors as a body. It is true we have exceptional cases where judgment is passed upon the labors of a co-worker in a given field, but it is generally done in such a way as to provoke a quarrel in the end, and even this occurs as a rule only between the members of rival institutions, or between men whose positions in life are considered fixed. For the young scholar who is looking for employment, or even after he has received an appointment, the criticisms of the older professors in his own institution or in others is regarded as the effusion of a restive revolutionary spirit which must be squelched forthwith."

[Mr. Storrow: Hullo, what is it? Mr. Buck thinks that will do.]

[Time 11.13.]

(Mr. Buck says the key makes a disturbing noise. It was suggested it better be taken out entirely, and he says he prefers to keep it in. Mr. Eaton has opened and closed the key once for each clause or phrase spoken. *The two operators change place, Mr. Eaton goes to listen at the receiving station and Mr. Buck takes his place at the transmitter.*)

[Time 11.17 1-2.]

[Mr. Storrow: Hullo, hullo, hullo! Well.]

Mr. Buck: Hullo, Mr. Eaton. Do you get that?

Mary and the dog.

The cat caught the rat.

Do you get that?

One, two, three, four, five.

Is that loud enough?

Won't you tell Mr. Smith if you get that all right?

Do I speak strong enough for you?

[Mr. Storrow (tell-tale line): Hullo, what is it? Speaking a little too loud, you have been.]

Mr. Buck: I speak a little too loud, do I?

Do you get that better?

One, two, three, four, five.

[Mr. Storrow (tell-tale line): Hullo, what is it? What is it?]

Mr. Buck: The dog barks. The dog barks. Do you get that?

Mary and the lamb.

[Mr. Storrow (tell-tale line): What is it? What is it? Too loud? Now listen.]

Mr. Buck: One, two, three, four, five, six, seven, eight, nine, ten. How do you get that?

The cat caught the rat.

The rat was caught by the cat.

One, two, three, four, five.

The cat was caught by the rat.

(This last phrase — the repetition — was spoken into the mouthpiece.)

Mr. Buck: One, two, three, four five.

The cat caught the rat.

One, two, three, four, five, six, seven, eight, nine, ten.

Mary had a little lamb. How do you get that?

[Time, 11.20.]

(Mr. Buck changes and puts on a fresh cell of the same kind of battery.)

Mr. Buck: I changed the cell.

One, two, three, four, five.

I changed the cell. Do you get that?

Mary had a little lamb.

Mary and the lamb.

The cat caught the rat.

The dog barks. How do you get that?

One, two, three, four, five.
Mary had a ball.
Mary caught the ball.
John and James. How do you get that?
[Mr. STORROW (tell-tale line): Well, what is it?
[Time, 11.22.]
What is it?
Yes. All right, listen.]
Mr. BUCK: Are you ready?
To the editor of the Nation.
To the editor of the Nation.
Then what is to be done?
To what is this due?
The first of these types.
[Mr. STORROW (tell-tale line): Well.
Talking too loud.]
Mr. BUCK: The first of these types.
[Time 11.23.]
Then what is to be done?
To what is this due?
[Mr. STORROW (tell-tale line): Well, what it?]

Mr. BUCK: "If the rules of the house were in fault, why not have reformed the rules of the house in a bolder and more stringent – –"

[Mr. STORROW (tell-tale line): Well?]

[Time 11.25.]

Mr. BUCK: "Now we wish very much that this state of things existed in England."

"We publish in another column."

"The actual professor is, however, a totally different person. He is mostly a modern American."

[Mr. STORROW (tell-tale line): Well, wait a minute.]

[Time 11.26.]

[Mr. STORROW (tell-tale line): Hullo, hullo. Are you ready, are you ready, are you ready? What is it?

Yes.

Yes. Are you ready?]

Mr. BUCK: All right, Mr. Eaton.

To what is this due.

To what is this due.

[Time 11.28.]

To what is this due.

To what is this due?

To what is this due?

To what is this due?

To what is this due?

To what is this due?

Then what is to be done?

Then what is to be done?

Then what is to be done?

Then what is to be done?

Then what is to be done?

Then what is to be done?

The first result will doubtless be to discredit the present government.

The first result will doubtless be to discredit the present government.

The first result will doubtless be to discredit the present government.

Then what is to be done?

Then what is to be done?

There is, however, another and perhaps a graver danger which the government have to face.

[Time 11.30.]

[MR. STORROW (tell-tale line): Hullo! hullo! hullo! Are you ready and listening? Hullo! are you ready? Say when you are ready.]

[Time 11.32.]

(Speaking in the mouthpiece.)

MR. BUCK: Harvard University finds itself in a position of considerable difficulty.

Harvard University finds itself in a position of considerable difficulty.

Harvard University finds itself in a position of considerable difficulty.

Harvard University finds itself in a position of considerable difficulty.

Harvard University finds itself in a position of considerable difficulty.

Harvard University finds itself in a position of considerable difficulty.

Harvard University finds itself in a position of considerable difficulty.

E divided by R plus R 1.

E divided by R plus R 1.

[Time 11.34.]

The dog barks.

The dog barks.

The dog barks loudly.

The dog barks loudly.

The dog barks.

The dog barks.

The dog barks.

The dog barks.

Bow-wow!

The dog barks. Do you get that?

The dog barks.

The dog barks.

The dog barks.

Stop now.

[Mr. STORROW (tell-tale line): Hullo. Stop now, that is the end, that is the end.]

[Time 11.36.]

(Mr. Buck put in an *induction coil*, the primary helix of which is one fifth of an ohm resistance, the secondary of which is one hundred and fifty ohms. One cell of the same battery and the *Reis transmitter* are connected in the primary circuit. The secondary circuit goes to the line and includes the receiver, which is now a *Bell magneto receiver* of the ordinary commercial form, furnished by the complainants.)

[Mr. STORROW (tell-tale line): Hullo, hullo. What receiver have you got in? What receiver have you got in?

Mr. MAYNADIER: It is the Bell magneto receiver of ordinary commercial form 91,258 A.]

[Mr. BUCK: One, two, three, four, five, six, seven, eight, nine, ten. Hullo. Do you hear that?

Do you hear the make and break of the circuit?

Do you hear the noise?

Mr. STORROW (tell-tale line): Did you hear that? We want to know if the circuits are right? Did you hear that opening of the circuit? Do you hear the noise from opening the circuit? We want to be sure the wires are all right. (The foregoing was merely to test the electrical connections.) Hullo. Now listen. Are you ready?]

[Time 11.39.]

Mr. BUCK (speaking on top): The horses run.

The horses run.

The horses run fast.

The horses are running.

The horses eat and drink. How do you get that?

The horses ran very fast. One, two, three, four, five.

A, B, C, D.

Six, five, three, four, two.

Am I speaking strong enough?

Six, seven, four, three, nine, two, one, five, twelve, twenty-seven, thirty-six, forty-four, ninety-five. How do you get that? Mr. Eaton, won't you tell me through the telephone whether you get that all right or not?

[Mr. STORROW (tell-tale line): What is it? What is it?

No, it is not Mr. Buck. What do you want to say to him?

Mr. Eaton says that he did get it all right.

Now listen.]

Mr. BUCK: Twenty-seven, sixty-three, ninety-five, forty-two, one hundred and one. I hope you got that all distinctly also.

[Mr. STORROW (tell-tale line): Well.

Too fast, Mr. Buck.]

Mr. BUCK: One, two, three, four, five.

The trustees of Williams College, Williamstown, Mass., received on Wednesday a bequest, I presume.

The event of the week was the formal opening, on Thursday, of the great suspension bridge across the East River, uniting New York and Brooklyn. In Brooklyn the day was made a holiday, and the business in New York was partly suspended.

(This is all on top.)

[Time 11.42.]

[Mr. Storrow (tell-tale line): Now Mr. Buck is going to speak something into the mouthpiece. Please listen carefully. Are you ready?]

Mr. Buck (speaking in mouthpiece): In Brooklyn the day was a holiday, and business in New York was partly suspended. Both the cities were decorated, the former in great profusion. In New York the exercises began at 12.35 o'clock. A review was held in City Hall Park. The ceremonies were concluded with music.

The ceremonies were concluded with music.
The ceremonies were concluded with music.
The ceremonies were concluded with music.
The ceremonies were concluded with music.
The ceremonies were concluded with music.
Do you get that all right now, Mr. Eaton?

[Time 11.44.]

(The arrangements now are: in the transmitting room one *modern carbon microphone* instrument, to be opened presently and its exact construction shown; battery, one Grenet cell for receiver; *Reis receiver* No. 2. The instruments connected in *direct circuit* without induction coil.)

[Mr. Storrow (tell-tale line): Hullo! hullo! Are you ready?]

[Time 11.53½.]

(*Mr. Eaton returns to the transmitting room and Mr. Buck to the receiving station.*)

Mr. Eaton: Hullo, Mr. Buck. One, two, three, four, five, six, seven, eight, nine, ten.

I suppose if you had on a magneto receiver you could hear this all over the room, but with that one there will be more difficulty, but you will get it fairly well.

Boston, Charlestown, Somerville, New York, Chicago, San Francisco.

[Time 11.55.]

Eighty-nine, seventy-four, thirty-three, seven, six, three, ten, one.

Is that all right? Can you get what I say, Mr. Buck? Hullo! I will read to you.

Local elections held in Virginia
Local election held in Virginia
Local elections held in Virginia
On Thursday were not
On Thursday were not
On Thursday were not
Encouraging to Mahone
Encouraging to Mahone
Encouraging to Mahone
Seven counties which had
Seven counties which had
Seven counties which had
Previously given readjuster
Previously given readjuster
Previously given readjuster
Majorities went Democratic.
Majorities went Democratic.
Majorities went Democratic.

[Time 11.57.]

(The microphone transmitter had been adjusted for talking strong right into it. *Reis receiver No.* 2 taken off, and *Reis receiver No.* 1 substituted for it. No other change.)

[Mr. STORROW (tell-tale line): Say when you are ready. Hullo, are you ready? Are you ready? Say when you are ready. Well, what is it? Are you ready?]

[Time 11.59.]

Mr. EATON: Hullo. I will read a little more to you.

The steamer "Pilot" blew up near Lakeville,
The steamer "Pilot" blew up near Lakeville,
The steamer "Pilot" blew up near Lakeville,
California, on Friday,
California, on Friday,
California, on Friday.

Eight were killed,
Eight were killed,
Eight were killed,
Seven wounded and ten missing.
Seven wounded and ten missing.
Seven wounded and ten missing.
The cause was insufficient
The cause was insufficient
The cause was insufficient
Water in the boiler.
Water in the boiler.
Water in the boiler.
The Harvard College overseers
The Harvard College overseers
The Harvard College overseers
On Wednesday postponed
On Wednesday postponed
On Wednesday postponed
The award of degrees
The award of degrees
The award of degrees
At commencement
At commencement
At commencement
Including a decision
Including a decision
Including a decision
Of the question of granting
Of the question of granting
Of the question of granting
To the governor the degree
To the governor the degree
To the governor the degree
Of LL. D.
Of LL. D.
Of LL. D.
New York, May 31st.

New York, May 31st.

New York, May 31st.

[Time 12.02 1-2.]

May 26th, Saturday.

May 26th, Saturday.

May 26th, Saturday.

A man of business should always have his eyes open.

A man of business should always have his eyes open.

A man of business should always have his eyes open.

Chesterfield.

Chesterfield.

Chesterfield.

Time 12.03 1-2.]

. Storrow (tell-tale line): Hullo. All right.]

Mr. Eaton: June 2d, Saturday.

June 2d, Saturday.

June 2d, Saturday.

Fortitude is the child of enterprise.

Fortitude is the child of enterprise.

Fortitude is the child of enterprise.

Wordsworth.

Wordsworth.

Wordsworth.

[Time 12.04 1-2.]

(In the transmitting room, Exhibit Reis transmitter, one cell of Grenet battery. In the receiving room, Exhibit Reis Receiver No. 1, *the two instruments connected in direct circuit.)*

[Time 12.10.]

Mr. Eaton (speaking at the top): Hullo, Mr. Buck.

It is a cat.

One, two, three, four, five.

How do you like this?

Boston.

One, two, three.

It is a cat.

It is a cat.

It is a cat.

Dog.
D-o-g.
D o-g.
D-o-g.
Do you hear me?
Do you hear me?
Do you hear me?
Do you hear me?
The horse is four legged.
The horse is four legged.
The horse is four legged.
How is that?
How is that?
Mr. Buck.
That is your name.
That is your name?
[Time 12.12.]
That is your name.
Do you hear it?
Do you hear it?
Do you hear it?
How does it sound?
How does it sound?
How does it sound?
One, two, three, four.
One, two, three, four.
One, two, three, four.
[Mr. STORROW (tell-tale line): Hullo, hullo. Listen carefully.]
[Time 12.14.]
Mr. EATON: Hullo. The May meeting.
The May meeting.
The May meeting.
Ladies night at
Ladies night at
Ladies night at
The Congregational Club.
The Congregati

Dinner and speeches
Dinner and speeches
Dinner and speeches
In Horticultural
In Horticultural
In Horticultural
Hall.
Hall.
Hall.
A paper of English
A paper of English
A paper of English
Congregationalism.
Congregationalism.
Congregationalism.
Opening of the New England
Opening of the New England
Opening of the New England
Woman's suffrage convention.
Woman's suffrage convention.
Woman's suffrage convention.
Business meetings
Business meetings
Business meetings
And so forth.
And so forth.
And so forth.
[Time 12.16.]
June 2, 1883.
June 2, 1883.
June 2, 1883.
It is a dog cart.
It is a dog cart.
It is a dog cart.
Cart.
Cart.
Cart.

How is that?
How is that?
How is it?
The Reis telephone.
The Reis telephone.
The Reis telephone.
The Reis telephone.
[Time 12.17.]
No. 81 Milk Street.
No. 81 Milk Street.
No. 81 Milk Street.
One, two three.
One, two, three.
One, two, three.
How is that?
How do you get it?
How do you get it?
How do you get it?

[Mr. STORROW (tell-tale line): Hullo, hullo. Say when you are ready. Hullo, hullo. Say when you are ready. *Reis receiver No. 2 now connected. Reis transmitter as before.* Yes, we are all ready. Now listen.]

[Time 12.20.]
Mr. EATON: Hullo. One, two, three, four, five.
One, two, three, four, five.
One, two, three four, five.
How is that?
How is that?
How is that?
May fifth.
May fifth.
May fifth.
May five times.
May five times.
May five times.
1883.
1883.

1883.
Hullo, do you get that, Mr. Buck.
It is a dog.
It is a dog.
It is a dog.
What time is it?
What time is it?
What time is it?
New York,
New York,
New York.
Boston,
Boston,
Boston,
Charlestown,
Charlestown,
Charlestown.
Ten, eight, three.
Ten, eight, three.
[Time 12.22.]
[MR. STORROW (tell-tale line): Hullo. Are you ready?]
MR. EATON. Choice flower seeds.
Choice flower seeds.
Choice flower seeds.
Flowering plants.
Flowering plants.
Flowering plants.
Trees.
Trees.
Trees.
Shrubs.
Shrubs.
Shrubs.
[Time 12 23.]
Roses.
Roses.
Roses.

Bulbs.
Bulbs.
Bulbs.
Easy lawn mower.
Easy lawn mower.
Parker's choice lawn grass seed.
Parker's choice lawn grass seed.
Parker's choice lawn grass seed.
Lawn house reels,
Lawn house reels,
Lawn house reels,
And hose,
And hose,
And hose.
Lawn seats and vases,
Lawn seats and vases,
Lawn seats and vases,
And lawn fertilizers,
And lawn fertilizers,
And lawn fertilizers.
Parker & Gannett,
Parker & Gannett,
Parker & Gannett,
49 North Market Street,
49 North Market Street,
49 North Market Street,
Boston,
Boston,
Boston.
Gardeners' Guide sent free to all who apply.
Gardeners' Guide sent free to all who apply.
Gardeners' Guide sent free to all who apply.
How is that? All right?
(All the foregoing spoken to the top of the transmitter.)

[Mr. STORROW (tell-tale line): Hullo hullo. Are you listening? Are you listening? Now listen, please.]

Mr. EATON: Hullo. There will be three sessions to-day

There will be three sessions to-day.
There will be three sessions to-day.
There will be three sessions to-day.
There will be three sessions to-day.
[Time, 12.26.]
There will be three sessions to-day.
There will be three sessions to-day.
There will be three sessions to-day.
(All this spoken in the mouthpiece.)
The first in the morning
The first in the morning
[Mr. STORROW (tell-tale line): What is it? What is it?]
Mr. EATON: The first in the morning
The first in the morning
The first in the morning
At half-past ten,
At half-past ten,
At half-past ten,
At half-past ten,
At half-past ten,
At half-past ten,
At half past ten,
Which will be devoted to business.
Which will be devoted
Which will be devoted
Which will be devoted
Which will be devoted
[Time 12.27.]
To business.
To business.
To business.
Which will be devoted to business.
(Speaking in the mouthpiece right along.)
In the afternoon
In the afternoon
In the afternoon
In the afternoon

At half-past two,
At half-past two,
At half-past two,
And in the evening,
And in the evening,
And in the evening,
At half-past seven.
At half-past seven.
At half-past seven.
At half-past seven.
Among the speakers
Among the speakers
Among the speakers
Will be Lucy Stone,
Will be Lucy Stone,
Will be Lucy Stone,
Will be Lucy Stone,
Mrs. Mary A. Livermore,
Mrs. Mary A. Livermore,
Mrs. Mary A. Livermore,
Mrs. Mary A. Livermore,
Mrs. Julia Ward
Mrs. Julia Ward
Howe,
Howe,
Howe,
Anna Garland Spencer,
Anna Garland Spencer,
Anna Garland Spencer,
And Miss Lelia Partridge.
And Miss Lelia Partridge.
And Miss Lelia Partridge.
And Miss Lelia Partridge.
How is that, all right?

(This last experiment was in varying tones of voice high and low, shrill and gruff.)

NOTES OF MR. LEIGHTON, SHORT-HAND WRITER, IN RECEIVING ROOM.

Present: Mr. Chauncey Smith, Mr. W. A. Copeland, Mr. Buck, Mr. Leighton.

Instrument, Defendants' Exhibit *Reis Transmitter* in transmitting room, in *direct circuit* with *magneto receiver No.* 9 in receiving room. Mr. Buck listening. He hears as follows: —

(Time 10 50½.) Now, Mr. Buck, did you get this all right? Halloo, Mr. Buck. (If I had a telephone, I should ask him to speak a little stronger, and I should hear all he said.)

All right. Do you understand what I say? (He doesn't speak quite strong enough.) (We are not permitted to give any instructions to the operator.)

1, 2, 3, 4, 5, 6, 7, 8, 9, 10. (10.54.)

(10.55.) (Little stronger.) Halloo, did you get that? Yes, now I will speak a little louder. How do you get this, Mr. Buck? 24 — 807. Do you get that all right? (with some numbers preceding, which I should have heard if I had not been talking myself.) That is a little too strong, I guess. Mr. Bradlaugh. (I understood that word. He is reading a newspaper. He has been reading a long passage from a newspaper, and I could hear occasionally a word. He was talking about Bradlaugh.) (10.59.)

(11.02½.) Halloo. Of American University — from the standpoint — of professional — causes for the present — education — cannot be. (He speaks a little too strong.) (11.04½.)

On every hand. (11.06½.)

Magneto receiver No. 10 now connected. *Reis transmitter* in *direct circuit* as before. Mr. Buck hears as follows: —

(11.09½.) Halloo, Mr. Buck. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Do you get that all right? Inefficiency — exceptional cases. (It simply breaks up. Speaking too strong.) (11.13½.)

Mr. Buck goes to transmitting room and talks into the Reis transmitter. *Mr. Eaton* receiving at magneto receiver No. 10 hears as follows: —

(11.17.) Halloo, Mr. Eaton; how do you get that? Do you get that all right? Counting. (Will you tell him that he is speaking a little too loud.) Little too loud, am I? (Too loud still.) 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. How do you get that? 1, 2, 3, 4, 5 — 1, 2, 3, 4, 5 — 4, 5. How do you hear that? 1, 2 — 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Mary had a little lamb. How do you get that? 1, 2, 3, 4. Do you get that? Mary had a little lamb. How do you get that? 1, 2, 3, 4, 5. (You tell him that I have the same trouble that he did; that he is talking while I undertake to say something. While I am repeating what he said he talks, and I lose it.) Are you ready? To the editor of the *Nation*. (Repeated twice.) (He is talking too loud.) (11.26.)

(11.27 1-2.) To what is this due? (Repeated it right over, but I could not swear to it.) To what is this due? To what is this due? What is to be done? What is to be done? What is to be done? Government. What is to be done? Government has to be. (11.31.) (11.32.) Invisible—Position—University—Considerable difficulty —University—Considerable difficulty—1, 2, 3, 4. Wait a moment. (I thought he said.) (11.35.)

With *Bell magneto receiver* No. 91,258 A now substituted as receiver; *Reis transmitter* as before. Induction coil. Mr. Eaton listening, hears as follows: —

The horses run very fast. (11.39.) How do you get that?

1, 2, 3, 4, 5.

A, B, C, D.

3, 4, 5.

(I would have got the rest of it if I had not been talking.)

6, 7, 4, 3, 9, 2, 1, 5, 44, 95.

Mr. Eaton, won't you tell me, through the telephone, whether you get that all right or not?

(11.41.) 63, 95, 32, 102 (or something); 1, 2, 3, 4, 5.

Wednesday.

Opening on Thursday of the great New York—Brooklyn —

(11.42½.) The business from New York was — suspended. (There is a word between.)

(12.35.) New York.

The ceremonies were concluded,

The ceremonies were concluded.

Do you get that all right now, Mr. Eaton? (11.45.)

Reis receiver No. 2. Transmitter is modern *carbon microphone.*

One Grenet cell of battery; *direct circuit.*

Mr. Buck, receiving, hears as follows:—

(11.53 1-2.) Hulloo, Mr. Buck.

1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

Magneto receiver — you could hear this all over the room; but with that one there will be more difficulty; but you will get it fairly well.

Boston—Charlestown—Somerville—New York—-Chicago—-San Francisco.

89—74—33—7—6—3—10—1.

Is that all right?

Can you get what I say, Mr. Buck?

Halloo, I will read to you.

Local elections held in Virginia. Local elections held in Virginia. Local elections held in Virginia.

On Thursday were not—On Thursday were not—On Thursday were not—encouraging to Munroe.

Seven counties—Seven counties which had—Seven counties—Readjuster—Previously given the Readjuster—Previously given Readjuster.

Majorities went Democratic — majorities went Democratic — majorities went Democratic. (11.58.)

Reis receiver No. 1 connected; *carbon microphone* for transmitter as before. Mr. Buck hears as follows: —

(11.59.)

Halloo — I will read a little more to you.

The steamer "Pilot" near Lakeville.

The steamer "Pilot" blew up near Lakeville. (Repeated again.)

California, on Friday — California, on Friday — California, on Friday.

Eight were killed — eight were killed — eight were killed.

Seven wounded, ten missing — seven wounded, ten missing — seven wounded, ten missing.

The cause was insufficient — the cause was insufficient — the cause was insufficient — water in the boiler — water in the boiler — water in the boiler.

The Harvard College overseers — the Harvard College overseers — the Harvard College overseers, on Wednesday, postponed — on Wednesday, postponed — on Wednesday, postponed — the report of degrees, at the Commencement — at the Commencement — at the Commencement — including a decision — including a — decision — including a decision on the question of granting — on the question of granting — on the question of granting — to the Governor the degree — to the Governor the degree — to the Governor the degree — of LL. D. — of LL. D. — of LL. D. — until May 31st — until May 31st — until May 31.

May 26, Saturday — May 26, Saturday — May 26, Saturday.

A man of business should always have his eyes open. A man of business should always have his eyes open.

(Repeated.)

Chesterfield—Chesterfield—Chesterfield.

Halloo—all ready.

June 2d—June 2d. Saturday, June 2d. Saturday.

Fortitude is the child of enterprise. (Repeated three times.)

Wordsworth—Wordsworth. (12.05.)

In transmitting room: *Exhibit Reis Transmitter* No. 1. One cell. Grenet battery. Direct circuit.

Mr. Eaton speaking.

Mr. Buck receiving, with Exhibit *Reis Receiver No.* 1, hears as follows: —

(12.09½.) Halloo. 1, 2, 3, 4, 5.

Mr. Buck—3, 4, 6—1, 2, 3, 4.

(12.13½.) Transmitter (I thought I heard the word).

43.

Halloo. (12.17½.)

Reis transmitter: Reis receiver No. 2 as receiver. Mr. Buck at receiver, hears as follows: —

(12.19½.) 1, 2, 3, 4, 5. (I wasn't sure of that, though.)

Boston—Boston.

(I almost hear. It breaks just enough to spoil it.)
Did you hear that? (12.29½.)
(I think the conditions are changed in some way.)

Examination of Prof. Dolbear resumed.

Int. 181. Have you caused to be prepared a general table and certain diagrams in illustration of certain statements in your deposition? If so, state by whom they were prepared under your direction, and produce them, and explain them briefly.

Ans. I have had such table and diagrams prepared by Mr. Henry C. Buck. I produce them. This table is an exhibit of the mathematical relations involved in the action of electricity in various ways when employed for the transmission of sounds and of speech.

In diagram No. 1 are represented the relations of electro-motive force to resistance, as involved in Reis's method.

In diagram No. 2, the same electrical relations in Wright's method.

In diagram No. 3, the same for Bell's method in the patents of 1876 and 1877.

In diagram No. 4, the electrical relations of electro-motive force and resistance in the commercial telephone.

In diagram No. 5, the electrical relations in my method.

In diagram No. 6, the electrical condition of a wire when subject to a charging current, as distinguished from an ordinary current of conduction.

Int. 182. What do the three curved lines mean in diagram No. 6?

Ans. The one which joins the two points E O represents the change in electro-motive force from the coil to the point O on the line at the instant when the first electrification reaches the point O, and the other two lines indicate the rise of potential at O on account of the accumulation of the electric charge because it cannot escape at O, so that the whole wire may become charged to the same potential which is here represented as dotted line P P′ parallel with the wire.

[*The table and diagrams produced are put in evidence, and marked "Defendants' Exhibits Table, Diagram No. 1, No. 2, No. 3, No. 4, No. 5, No. 6, W. A. C., Special Examiner."*]

Cross Examination resumed.

Cross-Int. 183. Is there anything in these papers which have just been put in that you had not previously testified to in your examination?

Ans. There is not.

A. E. DOLBEAR.

Subscribed and sworn to before me,

WILLIAM A. COPELAND,
Special Examiner.

DEPOSITION OF HENRY C. BUCK.

Direct Examination by J. E. MAYNADIER, Esq., *of Counsel for Defendants.*

BOSTON, June 2, 1883.

Int. 1. What is your name, and have you given two affidavits in this case?

Ans. Henry C. Buck; I have.

Int. 2. Please look at the table and diagrams now shown you,—defendants' Exhibit Table and Exhibits Diagrams Nos. 1 to 6,—and state who made them and explain what they represent.

Ans. I made both the table and the six diagrams.

The various formulæ represented in the table showing various currents of electricity are founded upon what is known as Ohm's Law, where the current is equal to the electro-motive force divided by the resistance.

The first case on the table, also Diagram 1, represent currents used in Reis's method, where E is practically constant as compared with the great variations in other methods. The three R's represent the entire resistance,—R, internal resistance of the battery; R_1, resistance of the line and receiver; and R_2, the variable resistance of the transmitter.

In the Figs. 1, 2, 3, of Diagram No. 1, the horizontal lines show resistances, while the perpendicular lines show the abstract electro-motive force of the generators; while the practical result would vary somewhat from any possible diagram, yet the diagrams are sufficiently accurate for all practical purposes.

R_2, representing the varying resistance caused by the transmitter, is small as compared with R and R_1.

The lines joining E and E′, Figs. 1, 2, 3, Diagram 1, represent a current where the entire resistance of the Reis circuit is uniformly distributed throughout the circuit.

Figs. 4, 5 and 6, Diagram 1, show an unequal distribution of the resistance, as when a transmitter and receiver are inserted in the line.

The second case on the table shows effects produced in Wright's method.

The primary circuit is quite similar to the Reis line, varying in this respect, however, that Wright reduces the resistance of R and R_1 of Reis, and increases the relative variations of R_2 as compared with the sum of R and R_1.

The Diagram No. 2, Figs. 1, 2, 3, 4, 5 and 6 show drawings made in accordance with the preceding formula, in which $R = 3$, $R_1 = 1$, $R_2 = 4$, 8, or 10, respectively.

Case II., *b*, formulates the operative current in Wright's transmitter and receiver. E increases until the potential is sufficiently high to overcome the resistance of R and R_1, when a discharge occurs.

Fig. 7, Diagram 2, shows this discharge by means of the dotted line connecting E and E_1.

Case II., *c*, formulates the inoperative *currents of charge* in Wright's transferrer and receiver, in which B_3 represents the constantly increasing resistance to the flow of the current caused by the decreasing difference of potential between the ends of an insulated conductor when subjected to a current of charge.

The value of B_3 at the beginning of a charge is zero; but rapidly increases to infinity.

Case II., *d*, represents the electrical attraction which doubtless took place in Wright's receiver, but which was not utilized by him.

Fig. 8 of Diagram 2 represents the same as Case II., *c*.

Case III. of table formulates the currents of Bell's patents of 1876 and 1877.

Diagram 3 shows the same thing, in which E is variable, which variations are very great as compared with the variations of Reis, but small as compared with those generated in the Dolbear system.

Case IV., *a*, formulates the currents of primary of commercial telephone, and are similar to those of Wright's primary, Case II., *a*.

Case IV., *b*, formulates the currents of secondary of commercial telephone which are similar to that of Wright's transferrer and receiver during discharge, shown in Case II., *b*.

Diagram 4, Figs. 1, 2 and 3 represent the primary circuit of commercial telephone, in which $R' = 2$, $R_1 = 1$, $R_2 = 3$, 7 and 11 respectively.

Figs. 4 and 5, Diagram 4, represent currents in secondary of commercial telephone, in which $R = 150$, $R_1 =$ line and receiver $= 150$.

Fig. 4 shows the conditions when electro-motive force is at its maximum, and Fig. 5 when at its minimum.

Case V., *a*, represents currents in Dolbear's primary which are also the same as in Wright's primary, Case II., *a*.

Case V., *b*, formulates the electrical attraction operative in the Dolbear receiver.

Case V., *c*, represents currents of charge in Dolbear transferrer, and similar to those found in Wright's transferrer and receiver, Case II., *c*.

Case V., *a* and *c*, are shown in Diagram 5, Figs. 1, 2 and 3 representing the Dolbear primary circuit; Figs. 4 and 5 showing the Dolbear secondary, in which there is an enormous variation between the maximum and minimum electro-motive force utilized. The maximum electro-motive force cannot be shown graphically, but is indicated by the broken line connecting E and E_1.

$R =$ the resistance of the secondary, which equals, say, 3,000 ohms; $R_1 =$ the resistance of the transferrer, and infinity is the practical resistance of the receiver.

Diagram 6 represents a charging current of an insulated conductor when one end is subjected to a high electro-motive force, when the initial charging will represent a varying electro-motive force in different parts of the line, which may be roughly indicated by the curved line connecting E O. Then the potential at O will increase and that at E decrease until the potential throughout the line is equal, as indicated by the dotted line P and P_1.

[*Complainants object to so much of the foregoing answer as refers to Reis and Wright, because it is inconsistent with and condradictory of the publications introduced by the defendants, from which they derived all their knowledge of Reis and Wright.*]

Int. 3. You criticised your Diagram 1, in that the lines representing electro-motive force were of the same length, each showing, say, four volts. Now, suppose the case of a generator capable of giving an electro-motive force of four volts plus at one pole and four volts minus at the other, and suppose the poles to be joined by an external conductor of very trifling resistance, and afterwards to be joined by an external conductor of considerable resistance, and explain how that would affect the difference of potential between the two poles, and the consequent current strength in the external conductor.

Ans. The four volts represent the abstract electro-motive force of the generator, and when the poles are connected by a conductor having no appreciable resistance, it becomes impossible for a great difference of potential to be produced at the poles, due to its neutralization by means of a current; and when a wire or conductor is provided having considerable resistance, the potential at the poles rises, and if the resistance be great enough, it rises until it reaches the maximum due to the electro-motive force of the generator, and the greater the difference of potential caused by the resistance the greater the rapidity of the current which is produced.

Int. 4. Please state what experience you have had in the use of these three instruments — Exhibits Reis Transmitter, Reis Receiver No. 1, and Reis Receiver No. 2, with the transmitter and one of the receivers in the same circuit; and state, also, how otherwise you have used these exhibits and with what results.

Ans. I myself bought in Europe, of the man who said he made them, the above-mentioned transmitter and receiver No. 1, in 1881. They were in exact imitation of those now held by the German government, and which were claimed to have been an original pair of instruments constructed for Reis. I myself compared these instruments with those original instruments which were exhibited at the International Electrical Exhibition, at Paris, in 1881, and found no appreciable difference. I have frequently experimented with those instruments, and also with receiver No. 2. The greater part of my experiments with these instruments were performed in the laboratory at Tufts College, that place being selected because comparatively free from noise, and the time was selected when noise was least likely to interfere with our experiments.

To produce the best and most satisfactory effects favorable conditions are essential.

I have frequently connected the Reis transmitter above mentioned in a direct circuit with one of the two receivers, and have, perhaps invariably, been able to hear counting and single words, and occasionally whole sentences, although this is a delicate experiment, and requires absolute freedom from all disturbing influences.

My experiments with these instruments have been varied in a great many ways, and have included many complex combinations, extending over a period of several years.

From these experiments I will briefly describe two or three. I have connected up this Reis transmitter with various receiving telephones in direct circuit, as, for example, a low resistance magneto-receiver. Under these conditions, if the person at the transmitter spoke in a voice of suitable strength, I was able to understand distinctly many sentences, and sometimes have been able to hear and understand nearly, if not all that was said at the transmitter, thus showing that the Reis transmitter is capable of producing an undulatory current. To produce these results it is desirable that the listener should have means of constantly communicating with the person who is transmitting.

I have also frequently connected these Reis receivers, No. 1 and No. 2, in direct circuit with any good modern carbon transmitter and been able to hear, while listening at the receiver, nearly, if not quite all that was said at the transmitter, this experiment going to show that the Reis receiver is capable of receiving. In this answer I have not referred to the tests which were made in the presence of the examiner and parties, because I did not understand that the question calls for it.

[*Adjourned.*]

BOSTON, June 4, 1883.

Int. 5. In your last answer you say that it is desirable that the listener should have means of constantly communicating with the person who is transmitting. Please explain more fully what you mean by that, and why it is desirable.

Ans. It has been my experience with the several Reis transmitters which I have used — I mean like Exhibit Reis Transmitter in all respects — that each instrument differs from the others in the loudness of tones to which it should be subjected for the best results; also the pitch, there is a certain pitch best adapted to each instrument. The Reis transmitters will not transmit properly when coupled in direct circuit, unless precautions be taken to maintain a suitable loudness and pitch in the voice of the person transmitting. This is why it is desirable for the listener to be able to give such necessary directions to the person transmitting as to varying the loudness and pitch when producing the best results.

Int. 6. Did you take part in the tests, May 31 and June 2, of the Reis receivers and the Reis transmitter in direct circuit with Prof. Dolbear and Mr. Eaton? If so, please explain the main difficulties under which those tests were carried on.

Ans. I did. As I said in the previous answer, it is quite desirable in experiments with these instruments that they be performed in a place free from all extraneous noises, both in the room and from the street. While listening at the receiver, during those experiments, there were several persons in the room at all times, some of whom were engaged in writing, and consequently more or less noise was produced. Moreover, the noise from the street was found to be quite a serious inconvenience while listening at the receiver, although the room may be regarded as in a quiet locality.

In a previous answer I also stated that it is essential that the proper degree of loudness of tone and pitch of the voice be maintained by the speaker while using the Exhibit Reis Transmitter. In all my previous experiments we have had means provided for giving such necessary directions to the persons at the transmitter. During the experiments we were not allowed to have direct communication. If I observed while listening at the receiver that the sounds were either-too strong or too weak, it was necessary for me to request Mr. Chauncey Smith, who was provided with the tell-tale line telephone, to inform Mr. Storrow to tell the speaker to speak a little stronger or a little weaker, as the case might be. It generally happened when this was done that the speaker took the other extreme, and the elaborate process had to be repeated. If I simply remarked while listening at the receiver that the speaker was speaking too loud or too weak, no attention was given to the remark by Mr. Smith.

Moreover, when I found by listening at the receiver that the conditions were nearly right for producing a sentence, I often hesitated to make request for a change, because thinking the conditions would the next moment come all right without my interference. I also frequently omitted to report the minor words, lest by so doing the sound produced by my voice should prevent my hearing a complete sentence.

Int. 7. Please state the best results which you personally have obtained with Exhibit Reis Transmitter in direct circuit with Reis receiver No. 1 as compared with the result of the tests last week when those two instruments were used together.

Ans. When I first experimented with Reis receiver No. 1 it was in much better condition than it was during those experiments of last week, since the sounding boards have become cracked and broken in several places. My former experience with receiver No. 1 and No. 2 compared was that No. 1 receiver produced much clearer tones, but that receiver No. 2 was the louder instrument.

I have heard longer sentences, louder talking and more distinct enunciation with receiver No. 1 during former experiments than I heard during those of last week. This I take to have been partly due to the poorer condition of the receiver during these experiments of last week, and partly to the conditions being much less favorable at those times.

[*Defendants here put in evidence the two magneto receivers referred to in the reports of the experiments of June 2d as Nos.* 9 *and* 10, *and they are marked "Exhibits Magneto* 9 *and Magneto* 10, *W. A. C., Special Examiner*."]

Cross Examination by J. J. STORROW, Esq., *for Complainants.*

Cross-Int. 8. Do you know as a matter of history when Reis died?

Ans. I believe it was in November, 1874.

Cross-Int. 9. Do the formulæ which you have given with reference to the Reis apparatus show that the currents are interrupted, or do they show that they are not interrupted?

Ans. It shows them uninterrupted, but varying in strength, due to the variations represented by R_2.

Cross-Int. 10. Does R_2 in that formula represent variations of electrical resistance which take place between the two electrodes of the Reis apparatus when their contact pressure is varied without interrupting the current?

Ans. It represents the electrical resistance at a given moment, which resistance may vary somewhat, but the current may not necessarily be interrupted.

Cross-Int. 11. Would you make the same answers with reference to the corresponding expressions in the formulæ, which you have marked "II., *a*, *b*, *c*," with reference to Wright's apparatus?

Ans. Whether R_2 would become infinity at any time would depend upon the energy acting upon the transmitter. It represents the varied resistance at the electrodes of the transmitter, which was at one time a minimum and then infinity. As I understand Wright to have used his resistance indicated by R_2 in his primary, the effect on the currents produced in the secondary shown in formula II., *b* and *c*, was to make them discontinuous or intermittent.

Cross-Int. 12. If I understand you, then, you mean that the currents in Wright's primary, and consequently in his secondary, were intermittent. Was that the case?

Ans. It was; although probably intermediate variations were present, but were not, as I understand, utilized by him.

Cross-Int. 13. Will you please tell me the weight of the free pendulum electrode of the carbon microphone which was used in the experiments of June 2?

Ans. Its weight is 367.7 grains.

H. C. BUCK.

Sworn and subscribed before me this fourth day of June, 1883.

WILLIAM A. COPELAND,
Special Examiner.

DEPOSITION OF WALTER R. EATON.

Int. 1. What is your name, age, residence, and occupation?

Ans. Walter R. Eaton; twenty-seven; Stoneham, Mass.; electrician, in employ of the Dolbear Electric Telephone Company.

Int. 2. What did you have to do, if anything, with the manufacture of these instruments, — Exhibits Reis Receiver No. 2, Reis Transmitter modified, Magneto 9 and Magneto 10, Reis-Thompson Receiver and Thompson-Reis Receiver and Reis-Leget Receiver?

Ans. I manufactured all of those instruments except the wooden cases, and those were manufactured under my orders, — the two Reis instruments, Reis receiver No. 2 and Reis transmitter modified, being copies of two instruments manufactured, as I was told, by Albert of Germany, except a piece of carbon has been substituted for the mercury cup in the transmitter and a binding post added for the purpose of cutting out the coil of the electro-magnet on the side of the box.

Int. 3. How does the modified Reis transmitter compare for efficiency with such transmitters as are now in common use?

Ans. The transmitter exhibited is not fully up to standard transmitters, because it requires more care in using, as it breaks too easy; but it is very much better than the unmodified Reis. I have carried on conversation by means of this transmitter over a line of an eighth of a mile or more, with two grounds in the line.

Int. 4. Did you assist Mr. Buck in the tests of the Exhibits Reis Transmitter and Reis Receivers 1 and 2 on June second?

Ans. I did, being at the transmitting end most of the time.

Int. 5. And prior to that day what experience had you had in the use of these three instruments, — Exhibits Reis Transmitter and Reis Receivers 1 and 2, and other instruments like them in construction and shape of all the parts?

Ans. For the last two years or more I have made various tests with these or similar instruments at different times. I have found that after carefully arranging the conditions I have never failed in getting from the receiver counting and familiar sentences, and oftentimes have heard sentences which I had no previous expectation would be sent to me. With the three instruments named I have not got as good results as with the instruments which are spoken of in the first answer as models from which I copied Exhibits Reis Transmitter modified and Reis Receiver No. 2.

Int. 6. Have you measured the resistance of the line when the Reis transmitter is in circuit with the Reis receiver No. 1?

Ans. I never have measured the whole circuit, but have measured parts of it. For instance, I have measured the Reis transmitter and found it to be about 2.3 ohms when the two posts of the transmitter were connected with the resistance coils by a short wire.

That is to say, what I measured was the resistance of the contact and the helix of the small electro-magnet on the side of the box, with the short wires which connect them. I have also measured the resistance of Reis receiver No. 1, and found it to be 1.4 ohms. I have also measured that of Reis receiver No. 2, and found it to be 1.3 ohms, and should judge that a couple of ohms would represent the resistance of the battery and rest of the line.

Int. 7. What are the resistances of the primary and secondary of the commercial telephone, ordinarily?

Ans. In the instrument that I measured I found in the primary circuit, when the instrument was in its normal position, between sixteen and seventeen ohms plus the resistance of whatever battery was used with it, and the resistance of the secondary coil I found to be about 155 ohms. To this will have to be added the resistance of the line and telephone receiver in order to get the resistance of the total secondary circuit. The resistance of the cell ordinarily used would be somewhere between one and two ohms, and the resistance of the primary coil and its connecting wires I found to be about .45 of an ohm.

Int. 8. Dividing the resistance, then, into three portions, that would make the internal resistance not more than two ohms, and the resistance of the primary wire about a half of an ohm, making together two and a half ohms, while the resistance at the electrodes, when the instrument is not in use, would be over fifteen ohms. Is that right?

Ans. That is right for the instrument I measured, Blake transmitter No. 72,519.

Int. 9. Please divide the Reis resistance as I just divided the resistance in the commercial telephone; that is, give the internal resistance and add it to all the external, except that at the electrodes of the transmitter.

Ans. In the experiments that I have usually performed we have used a bichromate battery of one cell, therefore the internal resistance would be less than an ohm in ordinary cases.

In the line there has generally been about six and a half ohms, which makes about seven and a half in the line outside of the contacts. I found the resistance of the contact of the electrodes to vary; when it would ordinarily work best it would be less than an ohm.

Cross Examination by J. J. Storrow, Esq., *of Counsel for Complainants.*

Cross-Int. 10. Magneto receiver No. 9 has for its magnet a permanently magnetized steel bar with a coil of rather coarse wire of one half ohm resistance wound over substantially the whole length of the core as shown on the diagram on the card attached to it, has it not?

Ans. It has.

Cross-Int. 11. Please describe the magnet, core and coil of magneto No. 10.

Ans. The magnet is a permanent steel magnet formed of either an octagonal or hexagonal bar about five inches in length and one half inch in diameter. About five eighths of an inch of this bar at the end nearest the diaphragm is turned down to a quarter of an inch in diameter. On this smaller portion is slipped a coil of No. 25 silk-covered wire, the resistance of which is about one and one half ohms.

Cross-Int. 12. Then this instrument, No. 10, is in its form, structure and arrangement the same as the ordinary commercial telephone of butter-stamp pattern, except that in your No. 10 the core inside the coil is of steel, instead of being a pole piece of soft iron, and the coil is wound with comparatively few turns of coarse wire, and is of low resistance. Is that the fact?

Ans. It is.

Cross-Int. 13. When did you manufacture the "Reis transmitter modified"?

Ans. It was in the summer of 1881.

Cross-Int. 14. Did you have the Exhibit "Reis Transmitter" at the time you manufactured the Exhibit "Reis Transmitter modified"?

Ans. I did not. Exhibit "Reis Transmitter" was brought from abroad after I had made the Exhibit "Reis Transmitter modified."

Cross-Int. 15. When did you make Exhibit "Reis Receiver No. 2"?

Ans. At about the same time that I made the transmitter.

Cross-Int. 16. Had you seen Exhibit "Reis Receiver No. 1" at the time you made Exhibit "Reis Receiver No. 2"?

Ans. I had not. "Reis Receiver No. 1" came from abroad after I had made No. 2. The coil originally on No. 2 was broken, and I have made a new one since.

Cross-Int. 17. When did you make magneto telephones nine and ten?

Ans. Since January of the present year.

Cross-Int. 18. When did you make Exhibits "Reis-Thompson Receiver" and "Thompson-Reis Receiver"?

Ans. I made them during the first part of the present year. I don't just remember the time.

Cross-Int. 19. What is the difference between them?

Ans. Nothing excepting the resistance of the coil, one being made of coarser wire than the other. "Reis-Thompson" is a quarter of an ohm, made of four layers of No. 18 wire. "Thompson-Reis" is about one ohm, No. 21 wire.

Cross-Int. 20. Each of these two Thompson instruments has a circular elastic diaphragm, three inches in diameter, made of wood and supported at the edges, have they not?

Ans. Yes.

Cross-Int. 21. When did you make the Exhibit "Reis-Legat Receiver"?

Ans. Nearly if not quite two years ago.

Cross-Int. 22. How long have you been in the employ of the defendants or any of them?

Ans. Two years about the first of last April.

WALTER R. EATON.

Subscribed and sworn to before me this fourth day of June, 1883.

WILLIAM A. COPELAND,
Special Examiner.

Circuit Court of the United States,

DISTRICT OF MASSACHUSETTS.

IN EQUITY.

No. 1628.

AMERICAN BELL TELEPHONE COMPANY
v.
AMOS E. DOLBEAR ET AL.

EVIDENCE FOR COMPLAINANTS IN REPLY.

TAKEN PURSUANT TO THE SIXTY-SEVENTH RULE OF THE SUPREME COURT OF THE UNITED STATES, IN EQUITY, AS AMENDED, BEFORE ME,

WILLIAM A. COPELAND, *Special Examiner.*

BOSTON, June 5, 1883.

Present: J. J. STORROW, Esq., *of Counsel for Complainants.*
J. E. MAYNADIER, Esq., *of Counsel for Defendants.*

DEPOSITION OF CHARLES R. CROSS.

Direct Examination by J. J. STORROW, Esq., *of Counsel for Complainants.*

My name is Charles R. Cross; I have already made two affidavits in this case.

Int. 1. Have you read the deposition of Prof. Dolbear which has just been completed in this case?

Ans. I have done so.

Int. 2. Do you find anything in that deposition which leads you to change your views as expressed in your affidavits?

Ans. I do not.

Int. 3. Do you find anything in that deposition which changes, in favor of the defendants, the state of facts before the court on the motion for preliminary injunction, — I mean apart from the consideration of the Reis apparatus which has now been introduced, but which the defendants did not place before the court on the motion?

Ans. I do not.

Int. 4. Mr. Dolbear has attempted a somewhat extensive chain of reasoning, employing mathematical formulæ for part of it, with the general purpose of supporting the allegations in the answer that Reis invented the electric speaking telephone, and made public property electrical transmission of speech by means of electrical undulations similar in form to the air-waves which constitute or accompany the words uttered into the transmitter. Will you state whether you find that attempted reasoning based upon any assumption as to the nature of the operation performed, and character of the currents employed by Reis; and if so, state what that assumption is?

Ans. The fundamental formula with which Mr. Dolbear begins his consideration of the subject, and which is found on page 388 of his deposition, is an expression of the well-known law of Ohm. In this formula the variables are E, electro-motive force, and R, R_1, R_2, which represent resistances of different portions of the circuit. If E is constant and R and R_1 are also constant, the strength of the current will be determined wholly by the magnitude of the variable resistance R_2. This formula as written will mathematically apply to a discontinuous or to a variable current, which latter may have any character according to the manner in which R_2 varies. If R_2 varies in correspondence with and proportion to the air vibrations produced by the voice, the electrical undulations resulting therefrom will be similar in form to the sound waves producing them. This result is reached in the ordinary microphone.

If, on the other hand, the variable resistance R^2 passes from a finite quantity to infinity, which occurs in any *circuit-breaking* instrument, the resulting value of the current will pass intermittently from finite quantity to zero. This is a condition which occurs in a circuit-breaking instrument, such, for example, as the Reis telephone transmitter. The formula used is a general mathematical expression, and can, of course, be made to apply to particular cases by giving the variables the particular values corresponding to such cases. Hence any mode of variation of the current can be mathematically represented merely by assuming one of the variables, as R_2, to vary in a particular manner.

In the application of this formula to the Reis instrument, as Prof. Dolbear applies it, there is the pure assumption that the variable R_2 varies its resistance in correspondence with the sound waves produced by the voice, so as to produce electrical undulations which are similar in form to those sound waves.

I quote from the paragraph to which I have already referred, page 388, of Prof. Dolbear's deposition the following: —

> "The introduction of this variable resistance R_2 constitutes Reis's great invention, as he was the very first, so far as I have any information, to vary the current strength in a circuit by means of the varying resistance operated by the energy of sound vibrations. It is precisely what is now known as microphonic contact."

Int. 5. If I understand you, the affirmation that this formula applies to the electical currents in any particular apparatus gives no information as to whether those currents are simply intermittent, or as to whether they are undulatory and of an articulating form, unless you also assume or ascertain whether R_2 passes alternately from a finite quantity to infinity, or whether, retaining always a finite value, that value changes in accordance with the sound waves. Is that the fact, or not?

Ans. Your understanding of the matter is entirely correct.

Int. 6. I understand that by the expression R_2 in this formula, Prof. Dolbear has referred to the changes, whatever they may be, which are produced by the action of the two electrodes of the Reis transmitter. Is that the fact?

Ans. That is the case.

Int. 7. Referring now to the physical conditions upon which depend the values of R_2 in this formula, as he uses it, I understand that whether the formula expresses a current which is intermittent, or whether it expresses a current which is never interrupted, but varies merely in accordance with the articulating undulations, depends upon the fact whether the electrodes of the transmitter alternately part company and interrupt the current and then close the circuit, or whether they simply vary their contact pressure without ever interrupting the current. Am I right about this; and if not, what is the fact about it?

Ans. Your understanding of the matter as stated in your question is correct.

Int. 8. Have you read the publications by and relating to Reis which have been put in evidence by the defendants, and also those which have been put in evidence by the complainants?

Ans. I have done so.

Int. 9. Will you state whether the intention of Reis, as expressed by himself and others in their publications, was that his apparatus, when in use, should interrupt the current with a frequency corresponding to the pitch of the sound which actuated the transmitter, or whether it was that it should merely vary the current without ever interrupting it?

[*Objected to because a variation of the current by increasing the resistance seems to the defendants' counsel one form of interrupting the current.*]

Ans. The intention of Reis, as stated in the various authoritative publications regarding his apparatus, was that the current should be interrupted — that is, reduced to zero — once for each vibration of the membrane, in correspondence with the pitch of the sound acting upon the membrane, so that the strength of the current should vary intermittently from a finite quantity to zero.

Int. 10. Considering the mechanical action of the two electrodes in the various forms of the Reis apparatus shown in the publications, do those publications state the intention to be that the two electrodes should part company with a frequency corresponding with the pitch of the sound which actuated the membrane, or do they state the intention to be that they should never part company, but always remain in contact?

[*Objected to as not within the province of the witness.*]

Ans. The publications state distinctly that the intention is that the two electrodes shall be separated from each other and again brought into contact with a frequency corresponding with the pitch of the sound actuating the membrane.

Int. 11. Turning now to those portions of the publications which purport to state the facts learned by actual use and observation of the Reis transmitter when in action, do they state that in actual operation the electrodes do part company and interrupt the electric current, or do they state that in fact they do not part company and do not interrupt the current?

Ans. They state that, as a matter of fact, in the operation of the instrument the electrodes do part company and so interrupt the current.

Int. 12. In several places in his deposition, particularly on pages 379 and 426, Prof. Dolbear undertakes to draw a distinction between breaking the contact and interrupting the current, and intimates that a statement that the contact was broken would not necessarily imply that the current was interrupted. Will you tell me whether, in the Reis publications, the precise phrase used to express the action of the apparatus upon the current is "breaking the contact," or whether it is "interrupting the current"?

[*Objected to, as the intimation set forth is not, in the opinion of defendants' counsel, found anywhere in Prof. Dolbear's deposition.*

Complainants quote from page 379: "*A distinction must, therefore, be kept in mind between a* break of contract *and a* break in current. *A* break of contact *does not imply a* break in current."]

Ans. The statement made in the Reis publications as to the operation of the apparatus in the original German is, that the *current* is *broken*, not simply that there is a break of *contact* or an interruption in the *circuit.*

Int. 13. If, in those parts of the publications which purport to state what was observed in the actual use and observation of the Reis apparatus when in action, you find stated any observed facts which go to show whether the apparatus did habitually break the current in the manner stated, will you please to mention some of those facts?

Ans. The transmitting apparatus of Reis is described as showing a spark at the contact points of the electrodes when the apparatus was in operation. The production of this spark is an evidence that the electrodes have parted contact. Also a rattling sound is described as proceeding from the electrodes, which indicates a parting of contact. Still further, the sound produced by the Reis receiver is described as being audible throughout a large room. This could happen only when the transmitter operated by breaking the circuit.

Int. 14. It appears from the statements in the Reis publications, and from the measurements introduced in evidence yesterday by the defendants' witness, Mr. Eaton, that the circuit employed by the various writers referred to employed a moderate length of line wire, three cores with coils inside them, the total resistance of the three being between three and four ohms, and two or three cells of battery, and a transmitter. In such an apparatus, would breaking the contact of the electrodes sufficiently to interrupt the battery current produce a spark at the break; and would a visible spark be there produced without interrupting the battery current?

Ans. A visible spark would not be produced by this apparatus unless the battery current was interrupted; and an interruption of the battery current would generally, and probably always, produce a spark.

Int. 15. If the apparatus operated in the manner described in the various publications, as stated in your previous answers, would it, when so operated, transmit articulate speech?

Ans. It would not.

Int. 16. It has appeared that the hopping electrode of the *Reis transmitter* weighs about seventeen grains, and that in the modern articulating microphones produced the electrode not attached to the diaphragm weighs from seventy-five to four hundred and sixty five grains.

Will you tell me whether this marked difference in physical structure adapts the one instrument to break the circuit and interrupt the current and the other to vary the current without interrupting it, when the same voice is applied to vibrate the diaphragms of both, and which structure is adapted for one purpose, and which for the other, and give your reasons?

Ans. The difference in structure referred to in your question is a matter of great importance. If the electrodes when actuated by the voice are to part company and so interrupt the current, they should be, and, as a matter of fact, always have been made light and caused to rest lightly upon each other.

This being the case, the impulse given by the vibrations of the voice will be sufficient to throw them out of contact with each other and thus secure the desired breaking of the circuit.

On the other hand, if the instrument is to be used as a variable resistance battery transmitter for the transmission of articulate speech, in which case the current must be simply varied and never interrupted, the electrode which is not attached to the diaphragm or immediately actuated by the motions of the diaphragm should be, and practically is given a considerable mass, in which case it is much more difficult to break the contact of the electrodes than if the second or anvil electrode has a less mass, while the variations in the pressure between the two electrodes, which are essential in the operation of such a transmitter, will be much greater, other things being the same, than if the anvil-electrode were lighter.

The reason of this is as follows: The electrode which is attached to, or in contact with the diaphragm, the hammer-electrode, as I will call it, presses more or less lightly against the anvil-electrode under the normal adjustment of the instrument when the instrument is not in operation. On speaking against the diaphragm motion is first communicated to the hammer-electrode. As this moves forward it of course tends to set the anvil-electrode in motion.

The larger the mass of the anvil-electrode the more slowly can any given velocity be imparted to it, and hence there will be an increased pressure between the two electrodes which, other things remaining the same, will be greater with a heavier anvil-electrode than with a lighter one. Similar actions occur in other portions of the vibration of the hammer-electrode. The mechanical resistance to rapid change of velocity in the anvil-electrode may be called "inertia resistance."

This same inertia of the anvil-electrode which prevents its acquiring rapidly the full velocity of the hammer-electrode also tends to prevent its moving away from the latter and so breaking the contact.

Int. 17. Please examine Mr. Dolbear's seventy-sixth cross-answer, page 405, which gives the weights concerning the anvil-electrode in Exhibit Dolbear transmitter; his answer to Cross-Int. 155, page 430, which gives the corresponding weights in the Reis transmitter; Mr. Buck's 13th cross-answer, page 483, which gives it in the carbon microphone used in some of the defendants' experiments of June 2d, and using your own knowledge of the weight of the anvil-electrode in the Blake transmitter, and of the structure, form and arrangement of the anvil-electrodes in these several instruments; state approximately in terms of weight what you have termed the "inertia resistance" of the anvil-electrodes in these several instruments.

Ans. I have used the term "inertia resistance" to indicate the mechanical resistance which occurs when one moving body exerts pressure upon another, thus tending to increase the velocity of the latter. If the second body acquires a simple motion of translation, or a motion which is practically a simple motion of translation, other things remaining the same, the resistance to change of motion will be immediately dependent upon its mass and may consequently be measured by its weight.

If the motion impressed upon the second body is partly or wholly a motion of rotation (as in the case of a bar pivoted at one end and moved by the application of a force at the other end), the distribution of the mass of the body, as well as the amount of the mass itself, is influential in determining that resistance. It is evident that in any case the resistance to motion at any moment of a mass which must move with a rotary motion will be equal to the resistance which some determinable mass would offer when acted upon by the same moving force, and that the weight of such a mass may be used to measure this resistance. It is to such a mass, as measured by its weight, that I apply the term "inertia resistance."

In the Blake transmitter the weight of the anvil-electrode is seventy-five grains, and as the motions of the different portions of the electrode are so nearly identical, this will represent very closely its inertia resistance.

In the pendulum carbon microphone used in the experiments of June 2d, the weight of the electrode, as in the case of the Blake transmitter, and for the same reason, very closely represents its inertia resistance. This weight is 367.7 grains.

In the Reis transmitter the weight of the hopping piece is sixteen and two tenths grains, and its pressure against the lower electrode eight and five tenths grains. The inertia resistance is, perhaps, ten grains.

In the case of the Dolbear transmitting apparatus, the weight of the electrode is four hundred and sixty-five grains, and the pressure between the electrodes fifty-seven grains. The shape of the electrode with its heavy horizontal bar at the end of two supporting pins, which themselves are quite long, gives it a very considerable inertia resistance, which is from seventy-five to one hundred grains.

Of course the effect of this bar is not to add sensibly to the pressure between the electrodes, since it rests directly over the supporting pins, and unless it tilts slightly to one side it does not affect the pressure between the electrodes at all.

Since, however, this bar is at some distance above the points of support, about which it rotates when set in motion by the hammer electrode, the resistance to motion or inertia resistance is very considerable in proportion to the pressure between the two electrodes.

The inertia resistance of these several instruments can be stated approximately as follows:—

Reis, say, ten grains.

Blake, say, seventy-five grains.

Dolbear transmitter, say, seventy-five to one hundred grains.

The pendulum microphone, say,

Int. 18. Please state whether it is or is not the practice with instruments composed of a diaphragm and free anvil-electrode, which are intended to produce in the current articulating undulations without interruptions, to construct the anvil-electrode with such weight and form as to give to it a notable inertia resistance.

Ans. It is the universal practice to do this.

[*Noon recess.*]

Int. 19. Referring now to the physical structure of the *Reis receiver*, is it an instrument which is calculated to give forth fairly audible sounds under variations of current which are exceedingly delicate as compared with current interruption produced in a circuit of moderate resistance and containing one or two cells of battery?

Ans. The Reis receiver produces, and is adapted to produce, only very feeble sounds when the current passing through it has its strength simply varied without actually breaking the circuit.

Int. 20. In the tests which the defendants made on May 31 and

June 2d, by applying to the Reis receiver what were, or what they claimed to be, undulatory currents as distinguished from intermittent currents, the listener applied the receiver closely to his ear. Do you find in the Reis publications any direction that it should be so applied or any statement that it was so applied?

Ans. I find no such direction or statement in any publications referred to.

Int. 21. In Prof. Dolbear's deposition, answer 39, page 384, he states that the Reis receiver was an instrument made "to sit upon a table like an ordinary telegraph instrument, as if Reis expected that the sounds produced by it might be loud enough to be heard by a room full of people." Does that statement substantially conform to the statements in the Reis publications, — both the earlier and the later ones?

Ans. It does.

Int. 22. When the Reis receiver is placed upon a table and actuated by a Reis transmitter operated to break the circuit, with a frequency corresponding to the pitch of the sound actuating it, will such receiver produce a sound loud enough to be heard by the bystanders?

Ans. It will.

Int. 23. When laid upon the table and connected with a Reis transmitter, operated so gently as not to interrupt the circuit, will the receiver produce sounds loud enough to be heard by the bystanders?

Ans. It will not.

Int. 24. Assuming that the Reis transmitter, as a structure, is to-day capable of producing to some extent electrical undulations similar in form to the sound waves, in the hands of those who have learned what was taught by Mr. Bell's patent and by the subsequent invention of the articulating microphone transmitter, will you state whether you find in any of the Reis publications any statement that it was desirable to produce such undulations as distinguished from interruptions as the means for transmitting speech or other sounds?

Ans. I find no such statement in any of the Reis publications.

Int. 25. Tell me whether you find in any of those publications any statement that electrical undulations similar in form to the actuating sound waves *could* be produced by the Reis transmitter.

Ans. I find no such statement whatever.

Int. 26. Do you find in any of the publications made by Reis, himself, anything which shows that he understood that difference in "form" between vibrations which gives to each sound its quality, as you have explained in your first affidavit?

Ans. I do not find in any of Reis's papers any statement showing that he understood the nature of musical quality.

He apparently had only the indefinite ideas which were popularly current when he wrote.

Int. 27. There have been put in evidence extracts from the catalogues of J. W. Albert, the mechanician, who, at Frankfurt a/M., manufactured and sold for Reis his telephone apparatus. One of these catalogues is for 1866 and the other for 1873. Each of them in connection with the telephone of Reis refers to certain books. Will you tell me what those books are and whether the references are to passages that have been put in evidence?

Ans. The references in the catalogue of 1866 are to Müller-Pouillet's "Text-book of Physics," sixth edition, Figs. 325–327, and to Pisko's new acoustic apparatus, Fig. 60.

The references in the catalogue of 1873 are to Müller-Pouillet, seventh edition, Figs. 348–350, and to Pisko, Fig. 60.

The passages as referred to in the catalogue of 1873 have been put in evidence in this case. The catalogue of 1866 refers to the same passage in Pisko; and apparently to the same passage in Müller-Pouillet.

Int. 28. When sounds of varying pitches within a moderate range of pitch are sung into the mouthpiece of the Reis transmitter so that it operates to interrupt the currents with a frequency corresponding to the pitch, as stated in the Reis publications, is there or is there not any difficulty in hearing sounds of a corresponding pitch in the Reis receiver connected therewith?

[*Objected to because it is physically impossible to operate the Reis transmitter in the manner supposed in the question.*]

Ans. There is not.

Int. 29. Did you attend the tests of the Reis exhibits, which the defendants made on May 31st and June 2d last week, and which are reported in Mr. Dolbear's deposition, pages 434–439 and 449–473.

Ans. I did.

Int. 30. Near the close of the test, on May 31st, notes of various pitches were sung into the mouthpiece of the transmitter, and were plainly heard, and the differences of pitch recognized by the listener. Do you remember that particular experiment?

Ans. I do; it is stated on pages 438, 439, *supra*.

Int. 31. Did you, while that particular experiment was going on, carefully watch the electrodes of the transmitter; and if so, what facts did you observe showing that the battery current was or was not interrupted?

Ans. I watched the electrodes of the transmitter very carefully while this experiment was in progress, and noticed a continuous series of sparks while the notes were sung, showing, evidently, that the instrument was operating as a circuit-breaker.

Int. 32. I have asked you from the reports of those tests introduced in Prof. Dolbear's deposition, aided by your own notes and recollection, to prepare a brief memorandum of what was accomplished during the attempts which the defendants made to transmit articulate speech with the Exhibit Reis Transmitter and the two Exhibits Reis Receiver No. 1 and Reis Receiver No. 2, which the defendants made May 31st and June 2d. If you have done so, will you please read it as a part of your answer?

Ans. I have done so, and it is as follows: —

The result with *Reis transmitter* and *Reis receiver No.* 1 on May 31st was as follows: —

The test occupied twenty-five minutes. Mr. Buck spoke into the Reis transmitter, and Prof. Dolbear listened at the Reis receiver.

Many familiar phrases and many newspaper sentences were spoken; regular numbers, one to five and one to ten, were counted; irregular numbers were counted.

The regular series was repeated thirty times; Prof. Dolbear heard them twice.

"How do you get that?" was repeated fourteen times; Prof. Dolbear heard it twice.

Prof. Dolbear heard "Mary had a little lamb" three times, and "Mary had a little" once. At the time when he thought he heard these words, no such phrase was uttered into the transmitter. This phrase had been spoken before, and was evidently a familiar one. This is all that was heard during the twenty-five minutes.

During the early part of the experiment the speaking was against the top of the transmitter. This is more likely to produce articulating currents without breaks than speaking into the mouthpiece is, and I think it was during this time that the only phrase and words heard correctly were transmitted. The Reis publications direct that the sounds should be made into the mouthpiece which is provided for that purpose.

Nearly all the speaking was done with a remarkably even and gentle voice, much below the loudness of ordinary conversation. Such force of voice as is used in ordinary conversation, if the mouth be applied to the mouthpiece, invariably caused breaks, manifested to one watching the transmitter by the well-known circuit-breaking sparks and rattling of the contact pieces.

Upon sounding into the mouthpiece sustained notes of different pitches, the circuit-breaking sparks were observed, and the different pitches plainly heard at the receiver.

The result on June 2d was as follows: —

Mr. Buck listened at *Reis receiver No.* 1; Mr. Eaton spoke to the *Reis transmitter*. The voice of the speaker was carefully modulated and gentle, below the tone of ordinary conversation, as on the previous day.

The experiment with *Reis transmitter*, coupled with *Reis receiver No.* 1, lasted eight minutes. Mr. Buck heard as follows: —

"Hallo," which was spoken.

"1, 2, 3, 4, 5," which was spoken.

"Mr. Buck," which was spoken.

"3, 4, 6," which was *not* spoken.

"1, 2, 3, 4," which was spoken three times.

"Transmitter" (he thought); it was *not* spoken.

"Hallo," which was *not* spoken at this time.

With *Reis transmitter* coupled with *Reis receiver No.* 2, the experiments lasted ten minutes. Mr. Buck heard as follows: —

"1, 2, 3, 4, 5," saying that he wasn't sure of it.

This series was spoken several times.

"Boston," "Boston," remarking I almost hear; it breaks just enough to spoil it.

"Did you hear that?" it was *not* spoken.

During this last test the voice was more varied; seldom, however, as loud as in ordinary conversation.

Int. 33. I have asked you to prepare in a similar manner to a memorandum of what was accomplished on June 2d by the defendants in their attempts to transmit articulate speech with Exhibit Reis transmitter and the two magneto receivers, No. 9 and No. 10.

Ans. I have done so, and it is as follows: —

Reis Transmitter and Magneto Receiver No. 9.

Mr. Eaton speaking to transmitter; Mr. Buck listening at receiver.

Time, 10.50–10.54. Mr. Buck thought he heard twenty words. Of these, the phrase "Do you understand what I say?" was not spoken. 10.55–11.07. Part of what Mr. Buck said he heard was not spoken. Of a long newspaper paragraph Mr. Buck repeated one word, "Mr. Bradlaugh," and said that he "could hear occasionally a word." 11.02½–11.04½. Newspaper paragraph of one hundred and ninety-two words read. Mr. Buck heard correctly detached phrases containing sixteen words, and one phrase of three words, "on every hand," which was not spoken.

Reis Transmitter and Magneto Receiver No. 10.

Operators as before.

Time, 11.10–11.13. Mr. Buck heard as follows: "Hallo, Mr. Buck"; numbers 1 to 10 and "Do you get that all right?" heard correctly. Newspaper paragraphs of one hundred and seventy-nine words read; Mr. Buck heard three only.

Same instruments; Mr. Buck transmitting and Mr. Eaton receiving.

During eighteen minutes the only result was as follows: —

11.17–11.35. Several familiar phrases, such as "How do you get that?" "Mary had a little lamb," etc., and regular numbers, 1 to 10, heard correctly.

Mr. Buck then picked out from the newspaper detached phrases of four to six words each, repeating them two to six times each; Mr. Eaton heard some of these correctly. Mr. Buck read some newspaper sentences, of which Mr. Eaton heard only detached words.

The foregoing was all spoken to the top of the transmitter, except one or two phrases.

Int. 34. I have asked you to prepare a similar memorandum as to their attempt to transmit speech with the Reis transmitter, arranged in the primary circuit of an induction coil, and the ordinary magneto receiver of the commercial form connected in the secondary circuit.

Ans. I have done so, and it is as follows: —

The *Reis transmitter* was arranged in the primary circuit of an *induction coil*, and the ordinary *Bell magneto receiver* of the commercial form connected in the secondary circuit.

Time 11.39 to 11.45. Counting, ordinary phrases and some newspaper sentences were uttered into the transmitter.

Some clauses, one complete sentence and one familiar phrase were heard.

Int. 35. I have asked you to prepare a similar memorandum as to their attempts on June 2d to transmit speech with the ordinary carbon microphone and Reis receivers No. 1 and No. 2.

Ans. I have done so, and it is as follows: —

Next experiment. A very powerful *modern carbon microphone* of Mr. Berliner's pendulum pattern was connected in *direct* circuit with *Reis receiver No.* 2. Mr. Eaton spoke into it quite loud and Mr. Buck listened.

Detached phrases spoken into it and repeated three times were heard with substantial correctness.

Same *transmitter* and *Reis receiver No.* 1. Experiment conducted in the same way, with substantially the same result.

I afterwards tested this transmitter with the ordinary commercial Bell magneto receiver. The volume of tone furnished by this transmitter was so great that the words could be understood when the Bell receiver was held a foot away from the ear, though the quality of the tone was rather poor, as is often the case with loud-speaking transmitters.

Int. 36. Have you ever yourself attempted to transmit speech with a pair of instruments substantially like defendants' Exhibit Reis Transmitter and defendants' Exhibits Reis Receiver No. 1 and No. 2? And if so, state whether the results you obtained were substantially the same as or substantially different from the results obtained by the defendants in the tests of May 31st and June 2d.

Ans. I have made such attempts with substantially the same results as those obtained by the defendants in the experiments under consideration. I have sometimes guessed out familiar or expected sentences largely by their rhythm, and sometimes I have imagined that I heard and understood sentences which, on inquiry, I found to be totally different from those spoken into the transmitter. I have never heard an unexpected and unfamiliar sentence transmitted by the instruments.

Int. 37. The defendants' Exhibit Reis-Legat Receiver has, among other deviations from the description in Legat's article, a piece of paper pasted over the pole of each magnet near the armature, and a soft bit of soft rubber placed between one of the poles and the armature. Will you tell me whether that addition is of any value, and if so, what, in an attempt to operate that instrument by feeble electric undulations and thereby produce speech?

Ans. The addition referred to is of great value, since it enables one to bring the armature much closer to the poles of the electros magnet without danger of its sticking to them in the case of accidental contact between the armature and the poles.

Int. 38. Would "sticking" interfere with the operation?

Ans. It would, since the armature would not be free to vibrate as it is intended to do.

Int. 39. Is it desirable or important to bring the armature very close to the magnet when the instrument is to be actuated by slight variations of current as distinguished from interruption of current?

Ans. It is very desirable to do this when varying, but not intermittent currents are used, since the effect of such a varying current upon the armature is greater in proportion as it is nearer to the poles of the magnet.

Int. 40. In his deposition, and particularly in page 358, Prof. Dolbear calls attention to the fact that in his receiver the pull between the flexible diaphragm next the ear and the substantially rigid plate or mass behind it varies inversely as the square of the distance. Will you tell me whether or not in the apparatus Fig. 7 of Mr. Bell's patent of March 7, 1876, the pull between the flexible diaphragm and its attached armature on the one hand, and the substantially rigid core of the electro-magnet on the other, does or does not vary inversely as the square of the distance, when the distance is varied?

Ans. Since the armature of the Bell telephone, as shown in Fig. 7 of the patent referred to, is permanently polarized, through its connection with the core of the electro-magnet, the attraction between the armature and this core will vary in the inverse ratio of the square of the distance.

Int. 41. On the same page, Mr. Dolbear refers to the fact that, under theoretical circumstances, the pull between the flexible plate of his receiver and the rigid mass behind it varies as the square of the electro-motive force, and not directly as the electro-motive force. Will you state whether the same law is true of the pull between the diaphragm and its attached armature on the one hand and the electro-magnet on the other, in Mr. Bell's apparatus of Fig. 7?

Ans. The same is true in the receiver of Mr. Bell, as shown in Fig. 7.

Int. 42. To avoid any misapprehension, I will ask you whether, in the various attempts by you or in your presence to transmit articulate sounds by the Reis transmitter and receivers, the operators sought to use the Reis transmitter, and so far as they attained any success at all, did use it so as to preserve a contact between the two electrodes, and thereby produce electrical undulations similar in form to the sound waves such as are described in Mr. Bell's patent, or whether they sought to use and did use it to produce breaks of contact and interruptions of current, as described in the Reis publications?

Ans. The transmitter was so used as to produce electrical undulations without breaking the circuit, as far as possible.

Cross Examination by J. E. MAYNADIER, Esq., *of Counsel for Defendants.*

Cross-Int. 43. In the great majority of all telephones now in use there is a very short battery circuit with an instrument in it sometimes called a microphone transmitter, and sometimes called a Blake transmitter, and sometimes called a battery transmitter. What, in your opinion, are the substantial differences between such a transmitter and Exhibit Reis Transmitter? Please name all that you believe to be substantial.

Ans. The Blake transmitter has a metallic diaphragm; the Reis instrument has a membrane diaphragm. The Blake transmitter has a narrow space in front of the diaphragm, between it and the mouthpiece; the Reis transmitter has a long speaking tube, and a cubical box between it and the membrane. The Blake transmitter has a heavy anvil electrode; the Reis apparatus a very light anvil electrode. The Blake is also furnished with an induction coil, though this is not essential; the Reis has no such induction coil.

In the Blake the rear face of the diaphragm and the electrodes are protected from disturbance due to extraneous vibrations by being completely closed within a box; in the Exhibit Reis Transmitter these electrodes are open to the air, although from the appearance of the instrument there may have been a glass cover placed over the electrodes.

The Blake transmitter is arranged so that the voice of the speaker acts directly upon the membrane without the intervention of any long speaking tube; in the Reis instrument the speaking tube is several inches long.

Cross-Int. 44. Do you not agree with me that the community is indebted to Reis for the initial step now used in the great majority of all telephonic apparatuses now in use, namely, the control of an electric current by the energy of air waves acting upon a diaphragm, which diaphragm acts immediately upon one electrode, through which the current passes, and through that electrode acts upon another electrode, through which the current also passes; and don't you also agree with me that Reis's invention of that method and apparatus is of equal rank, at least, with anything ever accomplished since, in the way of transforming the energy of sound waves into electric energy? If not, please explain why not.

[*Objected to because it is ambiguous in its most important clause, and because it misstates the work and method of Reis as defined by himself and associates.*]

Ans. The apparatus of Reis was certainly a very beautiful toy; but in view of the facts that his apparatus was barren of all useful results so far as the transmission of speech is concerned; that it is absolutely impossible to transmit speech by the method that he pointed out; that the electric current is not controlled by the energy of the air waves acting upon his diaphragm; that the first electrode acts upon the second electrode in such a manner as to intermittently and for short periods prevent the current from passing through any portion of the apparatus; and recollecting, also, that previous to the time of Reis musical sounds had been reproduced with the apparatus which he uses as a receiver, it does not seem to me that the community is indebted to him for the initial step used in the majority of telephone transmitters now in use. Both his transmitter and receiver are absolutely abandoned, and a mode of operation of which he had not the slightest conception is the only one which is or ever can be utilized for the transmission of speech. All that Reis really did, it seems to me, was to substitute a circuit-breaker operated by the voice for a circuit-breaker operated in other ways. He evidently hoped to do very much more, but the more extended his experiments, so far as is shown by anything that has been published, the less sanguine did his hopes or the beliefs of others become.

The method by which he expected to transmit the voice being an impossible one, his idea of using that method is valueless in the transmission of speech. Finally, in reference to the last few clauses of your question, Reis never transformed the energy of sound waves into electrical energy. He simply caused the circuit to be periodically broken, because of the energy of sound waves. In such a case as this, the energy of the sound waves is no more transformed into electrical energy than is the energy of the finger which pulls the trigger of a gun transformed into the energy due to the exploding powder; or the energy of the arm which opens a flood gate transformed into the energy of the stream which is let loose; or the energy of the hand that plants a seed transformed into the energy stored up in the tree that grows from it.

[*Adjourned.*]

BOSTON, June 8, 1883.

Cross-Int. 45. Please look at the instrument now shown you, [*now put in evidence, and marked "Defendants' Exhibit Reis Transmitter, First Form, W. A. C., Special Examiner"*], and state how it differs, if at all, from that form first described by Reis and others.

[*The exhibit and the name given to it objected to on the ground that it is totally different from anything described by Reis or others in the publications put in evidence, and is the direct opposite of the apparatus described by Reis in his lecture of October,* 1861, *in those particulars in which the production of an undulatory current as distinguished from an intermittent current depends.*]

[*In view of the objection of the complainants' counsel, the defendants' counsel adds to the questions the following:*] I refer you particularly to the report of Reis's lecture of 1861, and the cut therein contained.

Ans. Setting aside minor differences, I find this very important one. Speaking of the operation of his instrument, Reis says:

"If now tones or tone combinations are produced in the neighborhood of the block, so that sufficiently powerful waves reach the opening *a*, then these sounds cause the membrane *b* to vibrate.

"At the first condensation the hammer-like wire *d* is pushed back; at the rarefaction it cannot follow the retreating membrane, and the current traversing the strip remains broken, until the membrane, forced by a new condensation, again presses the strip (proceeding from *p*) against *d*. In this way each sound wave causes a breaking and closing of the current." [See the Lecture, pp. 541-2, *infra.*]

It appears from this statement that the construction of the hammer-like wire *d* is such that when the membrane moves away from it under the influence of a rarefied sound wave the wire *cannot* follow the membrane, so that the current is broken until the next condensation presses the strip that is attached to the membrane against this hammer-like wire. In the Exhibit apparatus now produced and referred to in your question the arrangement of the electrodes is totally different.

The hammer-like wire is attached to the end of a brass spring which presses this wire against the second electrode bearing upon it in such a way that it tends to follow and can follow the retreating membrane to a very considerable extent, thus preventing the circuit from being broken if the person speaking into the instrument uses a low or moderate tone of voice, thus bringing about simple variations in pressure at the contact point of the two electrodes without necessarily producing a rupture of contact.

Cross-Int. 46. You don't consider, then, that the thin strip of metal which carries the electrode *d* in Reis's cut is a metal spring?

Ans. My understanding of the apparatus is, that the thin strip of metal which extends from the binding screw *n* to a point over the middle of the membrane, there terminating in the platinum wire *d*, is not a flexible strip pressing the wire *d* into contact with the other electrode so that the wire *d* can follow this electrode in its retreating motion, but a stiffer strip or a strip so set that it does not tend to follow the membrane as it recedes.

Cross-Int. 47. But you do believe that the strip from the binding post *p* is a light metal spring, do you not?

Ans. The strip connected with *p* must be of such a nature as to allow the membrane to vibrate, and therefore is, I suppose, thin.

Cross-Int. 48. I suppose you meant to answer my last question in the affirmative by implication from the word "thin." Does not the same implication clearly apply to the thin strip from the binding screw *n*?

Ans. I do not know that the metal strip referred to in the forty-sixth question is necessarily a spring. All that the lecture says regarding the metal is, that there is a conducting strip of platinum cemented to the middle of the membrane and which is in connection with the binding screw *p*. Regarding the wire which is attached to the binding screw *n*, all that is said is, that there is likewise a thin strip

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tween the flexible diaphragm next the ear and the substantially the post *n* is substantially the same as the corresponding strip in the Exhibit Reis Transmitter, first form?

[*Complainants object to substituting anybody's guesses for the written description published by Reis himself.*]

Ans. I have nothing beyond Reis's statements by which I can form any opinion upon this matter. I am very certain that if any one were constructing apparatus to act in the manner in which Reis states as a matter of fact that his apparatus did act, he would not make the apparatus with a metal spring as shown in your "Exhibit Reis Transmitter, First Form," but would arrange the platinum wire so that it could not follow the retreating membrane, and the most natural mode of doing this would be to use a heavier or much stiffer strip of metal.

Cross-Int. 50. You mean, do you not, that he would make the piece of metal from binding post *n*, as Dr. Van der Weyde described it in his article, namely, not a "*thin strip* of metal," but a plate or bar substantially rigid, holding the electrode *d* away from contact with the electrode carried by the tympan when the tympan is not in vibration?

[*Complainants object that the question misstates the description by Dr. Van der Weyde.*]

Ans. He would certainly not use a piece of metal too thin to perform the function which Reis explicitly states was performed by the thin strips of metal referred to. It does not follow from this, it seems to me, that he would use a plate or bar. All that he would have to do would be to use a strip of metal which for convenience' sake be would probably make thin rather than thick, and which he would not mount in such a way as absolutely to defeat the object which, in his copy of the Reis apparatus, he intended to secure.

Cross-Int. 51. Considering now the later form of Reis transmitter (Exhibit Reis Transmitter), have you any doubt that the tympan of transmitters of that kind were, as a matter of fact, actuated by the energy of sound waves from vocal and other sounds, so as to produce in the circuit what it is now become common to call the "undulatory current," by which I mean variations in the strength of a voltaic current similar in form to the vibrations of the air accompanying the

upon the tympan of the transmitter, do you not?

Ans. I do.

Cross-Int. 55. You are also aware, are you not, that the Reis reof the block, so that sufficiently powerful waves reach the opening *a*, then these sounds cause the membrane *b* to vibrate.

"At the first condensation the hammer-like wire *d* is pushed back; at the rarefaction it cannot follow the retreating membrane, and the current traversing the strip remains broken, until the membrane, forced by a new condensation, again presses the strip (proceeding from *p*) against *d*. In this way each sound wave causes a breaking and closing of the current." [See the Lecture, pp. 541-2, *infra.*]

It appears from this statement that the construction of the hammer-like wire *d* is such that when the membrane moves away from it under the influence of a rarefied sound wave the wire *cannot* follow the membrane, so that the current is broken until the next condensation presses the strip that is attached to the membrane against this hammer-like wire. In the Exhibit apparatus now produced and referred to in your question the arrangement of the electrodes is totally different.

The hammer-like wire is attached to the end of a brass spring which presses this wire against the second electrode bearing upon it in such a way that it tends to follow and can follow the retreating membrane to a very considerable extent, thus preventing the circuit from being broken if the person speaking into the instrument uses a low or moderate tone of voice, thus bringing about simple variations in pressure at the contact point of the two electrodes without necessarily producing a rupture of contact.

Cross-Int. 46. You don't consider, then, that the thin strip of metal which carries the electrode *d* in Reis's cut is a metal spring?

Ans. My understanding of the apparatus is, that the thin strip of metal which extends from the binding screw *n* to a point over the middle of the membrane, there terminating in the platinum wire *d*, is not a flexible strip pressing the wire *d* into contact with the other electrode so that the wire *d* can follow this electrode in its retreating motion, but a stiffer strip or a strip so set that it does not tend to follow the membrane as it recedes.

Cross-Int. 47. But you do believe that the strip from the binding post *p* is a light metal spring, do you not?

Ans. The strip connected with *p* must be of such a nature as to allow the membrane to vibrate, and therefore is, I suppose, thin.

Cross-Int. 48. I suppose you meant to answer my last question in the affirmative by implication from the word "thin." Does not the same implication clearly apply to the thin strip from the binding screw *n*?

Ans. I do not know that the metal strip referred to in the forty-sixth question is necessarily a spring. All that the lecture says regarding the metal is, that there is a conducting strip of platinum cemented to the middle of the membrane and which is in connection with the binding screw *p*. Regarding the wire which is attached to the binding screw *n*, all that is said is, that there is likewise a thin strip

tween the flexible diaphragm next the ear and the sub the post *n* is substantially the same as the corresponding strip in the Exhibit Reis Transmitter, first form?

[*Complainants object to substituting anybody's guesses for the written description published by Reis himself.*]

Ans. I have nothing beyond Reis's statements by which I can form any opinion upon this matter. I am very certain that if any one were constructing apparatus to act in the manner in which Reis states as a matter of fact that his apparatus did act, he would not make the apparatus with a metal spring as shown in your "Exhibit Reis Transmitter, First Form," but would arrange the platinum wire so that it could not follow the retreating membrane, and the most natural mode of doing this would be to use a heavier or much stiffer strip of metal.

Cross-Int. 50. You mean, do you not, that he would make the piece of metal from binding post *n*, as Dr. Van der Weyde described it in his article, namely, not a "*thin strip* of metal," but a plate or bar substantially rigid, holding the electrode *d* away from contact with the electrode carried by the tympan when the tympan is not in vibration?

[*Complainants object that the question misstates the description by Dr. Van der Weyde.*]

Ans. He would certainly not use a piece of metal too thin to perform the function which Reis explicitly states was performed by the thin strips of metal referred to. It does not follow from this, it seems to me, that he would use a plate or bar. All that he would have to do would be to use a strip of metal which for convenience' sake he would probably make thin rather than thick, and which he would not mount in such a way as absolutely to defeat the object which, in his copy of the Reis apparatus, he intended to secure.

Cross-Int. 51. Considering now the later form of Reis transmitter (Exhibit Reis Transmitter), have you any doubt that the tympan of transmitters of that kind were, as a matter of fact, actuated by the energy of sound waves from vocal and other sounds, so as to produce in the circuit what it is now become common to call the "undulatory current," by which I mean variations in the strength of a voltaic current similar in form to the vibrations of the air accompanying the vocal and other sounds acting upon the tympan of the transmitter, and that such variations of current strength were always produced in every such transmitter ever coupled up in an electric circuit, and will be in all others that ever shall be so coupled up?

Ans. Your question is so broad in its references to the Reis apparatus that I find it somewhat difficult to answer it. It is certainly highly probable that accidentally and without their being recognizable undulatory currents have been produced. I have seen no evidence to show that they were ever produced intentionally prior to the date of Mr. Bell's patent. As to whether any Reis transmitter ever has been or ever can be fitted up without the production of undulatory currents to a certain extent, all that I can say is, that when the apparatus was not in use for transmitting sounds, such currents would very possibly be formed by the vibration of the membrane by extraneous noises, and even when the pitch of sounds was transmitted by the apparatus during the brief periods of contact of the electrodes, some such electrical undulations may have been produced. Of this, however, I am certain, that if produced at all, they were produced accidentally and unintentionally without any one's being aware of their existence, knowing how to produce them, or ever having conceived of the idea of producing and utilizing them; so that they were, at most, mere waste products.

[*Adjourned.*]

BOSTON, June 9, 1883.

Cross-Int. 52. You are aware, I suppose, that Exhibit Reis Transmitter when its diaphragm is submitted to a large class of vocal and other sounds will cause electrical undulations in the battery current similar in form to the air vibrations accompanying sounds of that class; and when subjected to another class of sounds will cause a peculiar intermittent current which is very similar to the air vibrations accompanying such sounds to a certain extent, but not sufficiently so for practical use in the transmission of speech, because of the fact that the current is not only interrupted, but at brief intervals actually ceases; the two classes of sound I have in mind are (those last referred to) all vocal and other sounds of an intensity sufficient to break the contact between the electrodes of the Reis transmitter and (those first referred to) all vocal and other sounds of an intensity insufficient to do that.

Ans. If the Exhibit Reis Transmitter is so operated that the method of Mr. Bell and not that of Reis is used, that is, if the electrodes instead of parting contact with each other as the diaphragm vibrates to and fro, remain in contact and so rest upon each other with a variable pressure, then electrical undulations will be produced. If, on the other hand, the method of Reis is used, such undulations will not be produced. The clause in your question which refers to the interruption and cessation of the current is utterly unintelligible to me, since the term "interruption of a current" has in electricity one meaning and one meaning only, that is, the breaking of the current.

Cross-Int. 53. I will repeat my question in a different form of words. You are aware, are you not, that the Reis transmitter is, under certain conditions as to intensity or loudness of sound, adapted for use under what you call the Bell method?

Ans. It is possible, with the Reis transmitter, to produce electrical undulations similar in form to the sound waves producing them.

Cross-Int. 54. And by electrical undulations, etc., in your answer, you mean precisely "electrical undulations similar in form to the vibrations of the air accompanying the" sound waves acting upon the tympan of the transmitter, do you not?

Ans. I do.

Cross-Int. 55. You are also aware, are you not, that the Reis receiver of the knitting-needle pattern will give out audible speech when actuated by currents of proper strength and form?

Ans. It is possible, as the defendants' experts have shown in this case, by using a very powerful modern microphone transmitter, to produce electrical undulations so powerful that with the knitting-needle receiver they will produce audible speech.

Cross-Int. 56. I don't think your answer is as responsive as it should be. Please answer the question again.

Ans. I do not understand in what respect my answer fails to respond to the question asked. If by "currents of proper strength and form" is meant currents which will cause the knitting-needle receiver to produce audible speech, my answer will of course be in the affirmative.

Cross-Int. 57. So far as you know or are informed, no telephones are now used practically and never have been used practically, in which the microphone transmitter and the magnet receiver were the same circuit. Is that so?

Ans. I do not know to what extent microphone transmitters and gneto receivers have been used in the same circuit; that is, with- an induction coil in actual practice. There is no difficulty, how- r, with short circuits in doing this, and it has very frequently n done for experimental purposes. It is customary to employ an ıction coil, but this forms no proper or necessary part of the smitter.

Cross-Int. 58. My question was as to what knowledge or infor- on you had, and in your answer you seem to take a different view of it. Please reconsider it and answer it again.

Ans. I did not intend to be irresponsive in my reply. I have not paid particular attention in my observation of various transmitters as to whether they had or had not induction coils in connection with them, but I have a very strong impression that abroad microphone transmitters have been practically used in the same circuit with magneto receivers. I will cheerfully look up the matter if it is desired.

Cross-Int. 59. You are aware, are you not, that when the resistance of the battery and of all the line is quite considerable as compared with the variation of resistance caused by the greater or less pressure of one electrode of the transmitter upon the other, the variations of current strength in the circuit are necessarily quite feeble?

Ans. In my replies to the preceding questions I did not ignore the effect of a large line and other resistance upon the effects of the microphone, but I have never found any difficulty in transmitting speech with such perfection as to loudness and clearness as would abundantly suffice for practical purposes when the microphone was in direct circuit with a magneto receiver of proper resistance. I have never attempted this when the line resistance was very considerable, in which case, of course, the induction coil becomes of great value.

It is true that when the line and other resistances external to the microphone are quite considerable as compared with the variable resistance of the microphone itself, the variations of current strength are necessarily much feebler than when the line and other external resistances are small, but the magneto receiver is such an exquisitely sensitive instrument that even when the current variations are much enfeebled it still enables them to produce distinctly audible speech.

Cross-Int. 60. Please explain what you consider to be the factor in current strength in the case of a microphone transmitter in direct circuit with a magnet receiver, whether of the knitting-needle or the magnet and armature sort; and be kind enough to consider separately the resistance of the generator, that of the line proper, and that of the helix of the magnet, and that of the electrodes of the transmitter when the tympan is not in vibration, as well as the varying resistance of those electrodes, and assume any definite line, say, a mile of line wire and a ground at each end, with all the conditions as favorable as they usually are in good practice.

Ans. The factors referred to are: (1.) The electro-motive force of the battery. (2.) The resistance of the battery. (3.) The resistance of the transmitter. (4.) The resistance of the line. (5.) The resistance of the receiver. (6.) The resistance of the earth connections, if this is appreciable. The electro-motive force of the battery may be assumed as about one and one half volts, the resistance of the battery as, say, one ohm, the resistance of t transmitter as, perhaps, ten ohms, the resistance of the line as, as twelve ohms, the resistance of the receiver, say, twenty-five ohms.

Cross-Int. 61. Do you think that any skilful electrician would ever put up a line with the internal and external resistance so largely different as you have stated it?

Ans. Of course, if an actual line were to be built, a more powerful battery might have to be used than that which I have assumed in my answer, that is, a battery consisting of several cells coupled so as to give a greater electro-motive force, and hence to produce a greater internal or battery resistance. In my previous answer I assumed only a single cell as being on the line, supposing that the question was simply intended to show the nature and approximate value of the variables, and not having in mind the question of their relative values. If several battery cells are used and coupled in the manner which I have mentioned, the electro-motive force will be increased in proportion to the number of the cells, while the battery resistance will be increased in the same ratio. The result will of course be an increased strength of current, but not necessarily a better effect. If any use is to be made of the numbers which I give, I should prefer assigning values to all of the variables after I understand the nature of the problem to be solved, since it is not customary to place a microphone in direct circuit with a magneto receiver at the distance of a mile away, and the choice of a battery with suitable electro-motive force and resistance to give the strongest current might interfere in certain ways with the normal operation of the microphone. Of course in any practical use of a transmitter, coupled in the manner described, there are several considerations apart from the mere maximum current obtainable which enter into consideration.

Cross-Int. 62. You have overlooked a portion of the Cross-Int. 60, namely, the variations in resistance caused by the varying pressure of one electrode upon the other. Assuming the normal resistance of these electrodes as ten ohms, what would, in your opinion, be the maximum and what the minimum caused by the action of the sound waves on the tympan of the transmitter?

Ans. That would depend very much upon the material and adjustment of the transmitter itself. Perhaps an average amount of variation would be two or three ohms. It is difficult, however, to measure the actual variation of resistance which occurs with a microphone transmitter, and the figures which I give are to be regarded as simply an estimate.

Cross-Int. 63. So far as you know, the more you can practically vary the resistance of these electrodes by the action of sound waves n the tympan of the transmitter, the more you increase the prac- l efficiency of the apparatus supposed, that is, the microphone nsmitter in direct circuit with the magnet receiver. For example, hen Prof. Dolbear telephoned between Boston and New York with hat apparatus, what must he necessarily have done so far as concerns the factors you have named?

Ans. Other things remaining the same, the practical efficiency of the microphone transmitter is increased with the increase of the variation in the resistance between the electrodes by the action of the sound waves. I have no knowledge whatever as to the alleged attempt of Prof. Dolbear referred to in the second part of your question, and therefore cannot state what he did or did not do.

[*Noon recess.*]

Cross-Int. 64. Now please explain the factors in the primary circuit when the microphone transmitter is used in a primary circuit of an inductorium, assuming a definite case and giving the length of line and the volts and ohms in that case.

Ans. In the primary circuit we have the following factors: (1) the electro-motive force of the battery; (2) the resistance of the battery; (3) the resistance of the transmitter; (4) the resistance of the primary helix of the induction coil and connecting wires.

The following values may be assumed: (1) 1.5 volts; (2) 1 ohm; (3) 10 ohms; (4) say ½ ohm.

Cross-Int. 65. It is clear to you, is it not, that the variations in current strength are enormously greater where the microphone transmitter is in the primary circuit of an inductorium than there can ever be practically when that transmitter is in direct circuit with the magneto receiver?

Ans. The variations are much greater in the majority of practical cases, but not necessarily so in all cases. The term "enormously" is hardly applicable, since the difference is by no means as great as I think it would generally be understood to be if that term were used.

Cross-Int. 66. Will you kindly give the figures of the numerator and denominator in the cases supposed in the preceding questions and answers, and also give the maximum and minimum denominators of the two cases?

Ans. The figures are as follows, assuming that a steady current is flowing through the circuit in each case: In the first case, the current is represented by the equation $C=\frac{E}{R}=\frac{1.5}{1+10+12+25}=\frac{1.5}{48}$. I have for simplicity's sake considered that there is only a single cell in the circuit.

In the second case, $C=\frac{E}{R}=\frac{1.5}{1+10+\frac{5}{10}}=\frac{1.5}{11.5}$.

Assuming that the maximum variation of the microphone resistance is in each case two ohms, and that the law of Ohm may be applied to the cases of maximum and minimum current, we shall have in the first place for the maximum current, $C=\frac{1.5}{47}$; the minimum current $C=\frac{1.5}{49}$; and in the second case for the maximum current $C=\frac{1.5}{10.5}$, and for the minimum current $C=\frac{1.5}{12.5}$.

From this it will be seen that in the first case the relation of the variation in resistance to the total resistance of the line is $\frac{1}{24}$ of that resistance or a little over 4 per cent. Whereas, in the second case the variation is $\frac{4}{23}$ of the total resistance, or a little over 17 per cent, that is, the variation in the second case is only about $4\frac{1}{4}$ times that in the first.

Cross-Int. 67. In the second case, where the microphone transmitter is in the primary of an induction coil, the electro-motive force generated by the secondary coil is enormously greater than the electro-motive force of the current in the primary, is it not?

Ans. The electro-motive force generated in the secondary when the microphone is placed in the primary circuit, other things being the same, is not dependent upon the electro-motive force of the battery connected with the primary circuit, but upon the variations in the strength of the current flowing through the primary circuit. The magnitude and rapidity of these variations will, other things being the same, determine the electro-motive force at any moment in the secondary circuit. Also, the greater the number of convolutions of the secondary coil the greater will be the electro-motive force produced by any given variation in the current flowing through the primary circuit.

If the variations are rapid, or if the secondary coil is a long one, the electro-motive force may become even enormously greater than the electro-motive force of the battery in the primary circuit.

Cross-Int. 68. You did not speak of the effect upon the electromotive force generated in the secondary of the resistance in the secondary line. Isn't it clear to you that if the poles of the secondary were joined by a short copper wire of large diameter the difference of potential of its two poles would be slight?

Ans. It is by no means clear to me that that is necessarily the case.

Cross-Int. 69. Please explain your last answer more fully, and particularly explain why it is that you think that one pole of the generator can have any very great positive charge, and the other pole any very great negative charge when they are joined by a short copper wire of large diameter.

Ans. I made no reference whatever in my reply to the last question to positive or negative charges, or to anything beyond the electro-motive force at opposite ends of the wire joining the terminals.

Cross-Int. 70. I don't get your meaning, unless you mean to speak of the maximum electro-motive force capable of being generated in a given coil under given conditions. If so, please explain how those conditions are effected, if at all, by joining the poles of the coil by a short, thick copper wire, or what is substantially the same thing, eliminating all external resistance.

Ans. The amount of electrical charge upon the terminals will, other things remaining the same, be much less when the terminals are joined by a short and stout copper wire than when this is not the case. There are a number of variable elements, however, which go to determine the effects which do take place under these circumstances.

Cross-Int. 71. Will you please to point out all the differences that you believe to be substantial between these two microphone transmitters, — Exhibit Reis Transmitter and Exhibit Dolbear Transmitter?

Ans. The first instrument is not a microphone transmitter; the second is. I notice the following differences in the working parts of the two instruments: The Reis circuit-breaking transmitter has a membrane; the Dolbear microphone transmitter has a metallic diaphragm. The electrodes in the Reis transmitter are of platinum; in the Dolbear transmitter of carbon. The upper electrode or hopping piece in the Reis transmitter is very light, having small inertia resistance, enabling it thereby to more surely break the circuit when in operation; the upper or anvil electrode in the Dolbear transmitter is heavy, and possesses a large inertia resistance, enabling it thereby to more surely preserve the continuity of the circuit when in operation. The Reis transmitter has a large cubical air chamber and a long speaking tube; the Dolbear transmitter has a very narrow air chamber and short mouthpiece. The Reis transmitter has its electrodes open to the air, although there has apparently been a covering glass placed over the electrodes, which glass is now missing; while in the Dolbear transmitter they are so enclosed as to be protected from extraneous noises. The Dolbear transmitter is also furnished with an induction coil which is not found in the Reis transmitter, the microphone being placed in the primary circuit of this induction coil; but so far as the operation of the microphone is concerned, this addition need not be considered.

Cross-Int. 72. Have you any doubt that this apparatus, including the box and its contents and connections, which is marked "Exhibit Dolbear Transmitter," would be a practical instrument as a transmitter if you should remove the transmitter now in place and substitute Exhibit Reis Transmitter in its stead?

For greater clearness, I will add, I mean take away the electrodes and diaphragm and diaphragm chamber and the speaking tube, which you call a mouthpiece, and substitute for them the electrodes and diaphragm and diaphragm chamber and the mouthpiece, which you call a speaking tube, of the Reis transmitter.

Ans. I am very certain that it would not.

Cross-Int. 73. Have you ever tried the apparatus suggested in the last question, and explain whether you feel certain that it would not work at all or that it would not work so well as the instrument marked "Dolbear Transmitter"?

Ans. I have never tried the specific apparatus mentioned in the last question, but from my knowledge of the Reis transmitter I am certain that it would not be practically available as a microphone transmitter. I do not assert that it would be absolutely impossible to transmit articulate speech by means of it under peculiarly favorable conditions and with skilled operators at both the transmitting and receiving instruments, but such transmission would involve the greatest care lest the instrument, in spite of the operator, should work as the inventor, Reis, intended to have it operate, and practically did operate it, in which case, of course, articulate speech would not be transmitted.

Cross-Int. 74 Do you not see a plain distinction between the apparatus as manufactured and described and pictured by Reis and others and the explanation of Reis and others as to how that apparatus was intended to work; that is, their *theory* as to how it did work?

Ans. If I understand the question correctly, I am asked if I do not see a difference between the apparatus itself and the views of the inventor as to its mode of operation. With this understanding, my reply is in the affirmative.

Cross-Int. 75. It seems to me quite clear from all the publications which I have read, taking them as a whole, that the Reis apparatus as used by Reis and others before 1870 did occasionally transmit vocal and other sounds by producing electrical undulations similar in form to the air vibrations accompanying the said vocal and other sounds. Don't you think it likely that it did? I mean the Reis transmitter in direct circuit with the Reis receiver, knitting-needle pattern, or the Reis-Legat pattern.

[*Complainants object to substituting anybody's theory of probabilities for the statements in the publications put in evidence.*]

Ans. The statements in the various Reis publications do not seem to me to make it at all clear that the Reis apparatus performed any such operation as that indicated in your question.

I do not deny the possibility that in spite of the endeavors of Reis to prevent it, the circuit may sometimes have remained unbroken and perhaps some sounds have been transmitted by the production of electrical undulations. I do not believe, however, that proper articulate speech was ever transmitted by the instrument prior to the invention of Mr. Bell's method.

Cross-Int. 76. I think we agree substantially, but I think you put too much emphasis on the sounds loud enough to break the circuit. Now, please answer my question, No. 75, bearing in mind that I have in my mind those instances in which the sounds acting upon the tympan of the transmitter did not break the current.

[*Complainants request the defendants' counsel to point out the instances referred to, if any such are named in the Reis publications.*

Defendants' counsel thereupon adds to the question the following:]

I mean every instance in which the two instruments are in circuit together, and vocal or other sounds, such as the sounds sometimes called extraneous noises in the room, talking and laughing going on in the room where the instrument was, and all other sounds acting upon the transmitter without breaking the current, and as one special example which I happen to recollect now, the reproduction of tones of various instruments, spoken of in Reis's lecture, page 542.

[*Complainants request defendants to point out the passage, if any such there be, where it is stated that the extraneous sounds referred to as made at the transmitting station produced by means of the apparatus any sound heard by the person listening at the receiver.*

Defendants' counsel again adds to the question:]

I don't ask you whether you think it likely that any one was listening at the receiver or not, because I don't care anything about that. I want your attention brought to the electrical undulations in the circuit whenever the tympan of the transmitter was set in vibration by sounds not loud enough to break the current, and I do not wish you to limit the word "transmit" in that question so that it will necessarily imply that any one was listening at the receiver, or even that the conditions were such that sounds could have been heard had any one been listening; but I do beg you to consider the question as to the electrical undulations similar in form to the air vibrations accompanying the said vocal and other sounds.

Ans. It seems to me that your question really asks me to state what, on theoretical grounds, might be expected to occur if the electrodes acted upon by extraneous sounds or otherwise did not part contact. Under those circumstances, theoretically, at least, as I have already said in my answer to the fiftieth cross-int., such minute electrical undulations might be formed.

[*Adjourned.*]

BOSTON, June 11, 1883.

Cross-Int. 77. I do not understand the word "minute" as used in your last answer, unless you mean currents of little strength. Please explain.

Ans. I mean undulatory variations of little strength in the current.

Cross-Int. 78. Can you illustrate in any way the strength of the electrical undulations similar in form to the vibrations of the air accompanying the vocal or other sounds acting upon the tympan of the Reis transmitter as compared with their strength in Bell's '76 patent, and also as compared with their strength when two magnet receivers of modern form are in circuit without a battery, one of them being used as a transmitter, and also as compared with their strength in the commercial telephone, by which I mean the one now generally used, with a microphone transmitter and battery in the primary and a magnet receiver in the secondary?

Ans. It is impossible to give any numerical estimate of the relative strength of the electrical undulations in the different cases referred to, as reliable experiments are totally wanting. It is evident, however, from the effects on the ear of a listener at the receiving instrument when the Reis transmitter is spoken into in such a way as to prevent the circuit from being broken, and so to act as a microphone rather than a circuit breaker, that the undulations are much smaller than when the same strength of voice is used with the instrument shown in Fig. 7 of the Bell patent, No. 174 465, or the ordinary magneto or the commercial telephone. I do not think, however, that mere difference of loudness is the only cause of the indistinctness of sounds produced by the Reis transmitter and receiver when operated as described. The electrical undulations which are produced when the transmitter is spoken into with such strength as to be just short of breaking the contact are, I think, very imperfect in form as well as minute.

Cross-Int. 79. In your affidavit you speak of diagram Fig. 1 and diagram Fig. 4, especially on page 23. Please state the resistance of the secondary coil when you used the arrangement shown in Fig. 4, as described in your affidavit, and found the transmission as good as in No. 1.

Ans. As nearly as I can recollect, the secondary used had a resistance of about four thousand ohms. I think it very possible that I may also have used a coil whose secondary had a resistance of nearly six thousand ohms, as I used such a coil in some of these experiments.

Cross-Int. 80. Was the comparison on page 23 between the arrangement shown in Fig. 4 and that shown in Fig. 1 when the very large coil, that is, of four thousand or six thousand ohms was used in both Fig. 1 and Fig. 4, or was the coil in Fig. 1 adapted to the helix of the receiver?

Ans. In these comparative experiments the same coil was used with each arrangement.

Cross-Int. 81. Then in Fig. 1 did you have a special receiver whose coil had somewhere near four thousand or six thousand ohms' resistance?

Ans. I used the ordinary receiver, which had a resistance of about seventy-five ohms.

Cross-Int. 82. Then it is mathematically certain, is it not, that the arrangement shown in Fig. 1 with a four-thousand or six-thousand ohm secondary and a seventy-five ohm receiver was very much less efficient than if the secondary coil had had seventy-five ohms instead of four thousand or six thousand, — assuming, as I do, that the line wire was of very little resistance, say less than ten ohms?

Ans. Not at all. Undoubtedly the efficiency of the current with a high-resistance coil and low-resistance receiver is less than if a high-resistance receiver was used. If, however, we make use of the same receiver and increase the number of convolutions of the secondary helix, thus increasing the resistance of the secondary helix, the current throughout the whole circuit will be increased. It is clear that this must follow, since we have increased the electro-motive force in very nearly the same ratio as we have increased the resistance of the secondary coil; but the resistance of the whole circuit is not increased proportionately, so that we have a greater electro-motive force in the circuit, but not a proportionally greater resistance. The effect upon the ear in the two cases would not, however, be very marked. It is generally quite surprising to one who is not practically familiar with the subject to find how slight a variation in the loudness of a telephone ensues, even when there are very great variations in the relative resistances of the receiver and the secondary helix of the induction coil.

The sound produced with the arrangement in Fig. 4 was probably somewhat less loud than with the arrangement shown in Fig. 1, but not sufficiently so to have led me to make any particular note of it at the time, although my notes were very full and intended to include every point which I noticed. I have repeatedly performed the same experiment since, with low-resistance secondary coils, and have always obtained clear, distinct and intelligible speech.

Cross-Int. 83. You agree with me, if I understand you, that the best results are obtained in the arrangement shown in Fig. 1, where the secondary coil is adapted to the line and helix of the receiver by making the resistance of the former equal to the sum of the latter.

Secondly, that the efficiency of the current strength was a fraction only when the four-thousand or six-thousand secondary was used with a seventy-five ohm receiver of what it was when the proper coil was used with a seventy-five ohm receiver.

And, *thirdly*, that the current strength in the arrangement show in Fig. 4 was excessively minute as compared with that when the proper secondary coil was used with a seventy-five ohm receiver, or even as compared with that when a high-resistance coil was used with a seventy-five ohm receiver.

If you don't agree with me as to my qualifying phrases (which you readily see the defendants' side are apt to make more intense than the complainants' side), please illustrate numerically, if you can, the current strength in the three cases.

Ans. It is customary to give the secondary coil a resistance approximately equal to the sum of the resistances of the line and helix of the receiver. As I have already indicated, however, this ratio can be very widely departed from without producing any very perceptible effect upon the ear. The acoustic effect is not in any way proportional to the electrical currents, since, as is well known, the effect upon the ear is not proportional to the mechanical energy of the air vibrations acting upon it.

The current strength with the high-resistance coil and seventy-five ohm receiver was, as I have stated, greater than if a low-resistance coil had been used.

The current strength in the arrangement in Fig. 4 was not, so far as could be perceived by the ear, from the sound produced in the magneto receiver, very much less than when the arrangement of Fig. 1 was used. It is always exceedingly difficult to make any numerical estimate of the loudness of different sounds, and, as I have stated, my notes taken at the time make no allusion to any difference. As the experiments were made nearly a year and a half ago, I do not of course carry a distinct recollection regarding the matter. I do recollect distinctly, however, that the articulation obtained with the arrangement in Fig. 4 was at least loud enough to be efficient for practical purposes,—was perfectly clear and distinct. This result was exactly what I expected to get, since the capacity of the human body with which the terminal of the magneto-receiver was connected is quite considerable.

Cross-Int. 84. You appear to me to assume that the resistance of each convolution of the 4,000 or 6,000 ohm coil was the same as that of any other convolution and also that the electro-motive force generated by each convolution was as great as that generated by any other convolution: is it not clear that this assumption is purely theoretical, and that the effect is that some of the coils give a maximum electro-motive force and a minimum resistance, while others give less electro-motive force and more resistance, and others still less electro-motive force and still more resistance, until you come to those which, in the 4,000 or 6,000 ohm coil spoken of, give the maximum resistance and the minimum electro-motive force, so that as a matter of fact a limit is very soon reached in building secondary coils where every convolution diminishes slightly rather than increases the current strength?

To make it clearer, I will add an example: is it not true that a low-resistance secondary coil having each of its convolutions arranged to the best advantage possible will generate greater current strength than any high-resistance coil such as you used in the arrangement, Fig. 1 and Fig. 4?

Ans. It is undoubtedly true that if, keeping the length of the axis of the coil the same, successive convolutions of wire were added, a limit would be reached as you suggest; but, as a matter of fact, the length of the induction coil is always increased with the number of whorls of the helix used, it being customary to build all large coils in similar sections, each section consisting of a flat disk-shaped bobbin placed upon the soft-iron core of the induction coil. If, say, ten of these bobbins were used, both the electro-motive force and the resistance of the coil would be ten times as great.

If we compare, however, a small coil, like that of a Blake transmitter, with such high-resistance coils as I used in the experiments referred to, I think that the current through the seventy-five ohm receiver is necessarily greater with the large coil than with the small coil, since, as a matter of actual fact, the large coil gives so high an electro-motive force as to be capable of throwing a spark through an inch and a half of air, while the coil of the Blake transmitter will not produce sufficient electro-motive force to throw a spark through more than a very minute thickness of air.

The electro-motive force with a large coil is, therefore, enormously greater than with a small one.

Now, if we replace the air resistance in each case by that of the resistance of the magneto receiver of seventy-five ohms, the difference of potential produced between the two terminals of a coil being still much greater in the large coil than in the small coil will give a stronger current through the external resistance. In this consideration I have not taken into account differences depending upon variations in the time requisite to produce current variations in the coils, which circumstance may have a very important effect upon the results obtained with different receivers and coils of different resistances.

[*Noon recess.*]

Cross-Int. 85. I think you confuse electro-motive force and current strength in a part of your last answer; and also that you confuse the different bobbins making up a large coil with the different convolutions making up each bobbin; and also that you are speaking theoretically, merely, when you say that ten bobbins will give ten times the electro-motive force of one bobbin, and therefore I ask you, is not the current strength precisely the same with one volt electro-motive force and one ohm resistant as with one hundred volts electro-motive force and one hundred ohms' resistance, or one million volts electro-motive force and one million ohms' resistance? *Secondly*, is it not true that the innermost convolution of each bobbin generate greater electro-motive force and offers less resistance than any convolution farther away from the axis of the core? And, *thirdly*, is it not true that that bobbin nearest the pole of the core generates a greater electro-motive force than any other bobbin in the case of the ten bobbins supposed by you?

Ans. I do not think that there is any confusion of ideas in the reply which I made to your last question. My reply is, of course, incomplete, for the reason that I cannot make it complete without writing what will be virtually a disquisition on electro-dynamics, and I will also remark that in a number of these questions which I have endeavored to answer as clearly as possible within any reason-able limit of time and space, the assumptions made are such that I must answer "theoretically" and incompletely, as the questions themselves omit to take into account a great many elements which must necessarily be taken into account in any thorough consideration of the subject. In reply to the first of your questions, for steady currents the current strength is precisely the same when the electro-motive force is one volt and the total resistance in the circuit is one ohm as when both the total resistance and the total electromotive force are multiplied by 100 or 1,000,000.

Second. The innermost convolution of each bobbin offers less resistance than any convolution farther away from the axis of the core, but it does not necessarily generate greater electro-motive force, although the electro-motive force generated in any given unit of length of the convolution diminishes as that convolution is farther away from the axis.

Third. The bobbin nearest the pole of the core probably does generate a somewhat greater electro-motive force than the middle bobbin upon the core. I do not see, however, that any of the considerations mentioned in this question affect the truth of the statements which I have made in my replies to your preceding questions.

Cross-Int. 86. I have been taught that a simple convolution arranged in the best possible practical relation to the core will generate a greater current strength than any other number of convolutions. Do you dispute this, using the term "current strength" as the quotient obtained by dividing the electro-motive force by the resistance, and leaving out of view the fact that certain electro-motive force is necessary for certain uses and fatal for certain other uses?

Ans. The question is not perfectly clear. If there is any resistance in the circuit other than that of the convolution itself, your supposition is certainly untrue; if there is no resistance other than the convolution itself, your supposition is a truism.

Cross-Int. 87. Have you ever had any practical experience in the construction of electrical apparatus or in the management of such apparatus, or in putting up circuits for use with such apparatus; or is your knowledge wholly that derived from study and experimental research?

Ans. I do not quite understand the question. I have not had occasion to spend a great deal of my time in the mechanical work of putting up circuits or construction with my own hands of very many pieces of electrical apparatus. My knowledge of electrical apparatus is not by any means confined to what are ordinarily known as instruments for research, especially in connection with telephony, since I have been familiar with that subject from its beginnings, and have been conversant with the whole subject, both in its theoretical and practical aspects.

Cross-Int. 88. You have doubtless heard very loud talk from a magneto-receiver, have you not?

Ans. I have.

Cross-Int. 89. And you are aware that that very loud talk was because of very great current strength flowing through the helix of the receiver, are you not?

Ans. It was because of very great *variations* in current strength.

Cross-Int. 90. You are also aware, are you not, that in order to make a magnet receiver speak loud enough to be heard as you now hear my voice, that is, over all extraneous sounds and several yards away from your ear, very much greater variations in current strength are necessary than can be obtained in the present commercial telephone?

Ans. I am.

Cross-Int. 91. You have, in your answers to Cross-Ints. 43 and 71, pointed out all the differences that you believed substantial between Exhibit Reis Transmitter and Exhibit Blake Transmitter, and all the differences between Exhibit Reis Transmitter and Exhibit Dolbear Transmitter: will you now tell which of the differences you find described, suggested, or in any way hinted at, in either of the Bell patents in suit?

Ans. The differences which I have pointed out were, of course, simply differences in the mechanical construction of the various parts of the apparatus. Neither of the specific forms of transmitter shown in the exhibits is described in either of the Bell patents, and, therefore, I do not find that any of the specific differences which I have pointed out are mentioned there. It is evident, however, from the construction of the exhibits referred to, that the Dolbear transmitter is intended to be operated according to the manner described in the fifth claim of that patent, while the Reis transmitter is not adapted to be operated according to that manner.

Cross-Int. 92. You have used the word "method" in your affidavit, and I believe in some places in this deposition, and in your last answer you use the word "manner," and your use of those terms seems to me very peculiar: do you think that causing electrical undulations similar in form to the air vibrations accompanying certain vocal and other sounds is a "method" of transmitting vocal or other sounds telegraphically or a "manner" of transmitting vocal or other sounds telegraphically?

Ans. I do.

Cross-Int. 93. Is it physically possible to transmit sounds, in the sense in which you have used that term, by means of electrical energy differing widely in form from the form of the air waves which, when acting on the ear, give rise to such sounds?

Ans. If I understand the question, I am asked if it is physically possible to transmit sounds with all their characteristics, except by producing electrical undulations similar in form to the sound waves which produce them. Understanding the question in this sense, my reply is that I do not consider it possible to transmit sounds with all their characteristics, except by producing such electrical undulations.

Cross-Int. 94. My question is much the same; is it not, in your opinion, as if I had asked you whether it were possible or not for any agent to do work for which it is not fitted?

Ans. No.

Cross-Int. 95. If I should speak to a pane of glass mounted in close proximity to one face of an insulated cube of metal, with an insulated wire, say, a few feet long or longer, with one of its ends in electrical contact with the insulated cube, and the insulated cube and its wire were electrified or charged with electricity, a thin air space existing between the pane of glass and that side of the electrified cube with which it is parallel, and to which it is nearest, would I not cause electrical undulations similar in form to the air vibrations accompanying the vocal sounds made by me in speaking?

Ans. I could answer your question with much more certainty as to what would certainly be the effect produced if I had the knowledge given by experiment to guide me than it is possible for me to do with nothing but your supposition before me.

Cross-Int. 96. Can you not see a plain distinction between necessary conditions under which all must work who desire to accomplish a certain end and a method of accomplishing that end capable of being put into practical use at the benefit or convenience of the community; and have you not in your affidavit, and in many places in this deposition, used the terms "method" and "manner" to mean both of these things?

Ans. Of course I see clearly that logically a distinction such as you make in your question can be entertained. There is always a distinction between a physical law and a process based upon that law. I have frequently in my affidavits and deposition spoken of the "method" of transmitting speech invented by Mr. Bell. Whether or not I have used the term "method" in different senses I can easily explain if any specific passages are pointed out to me.

Cross-Int. 97. Is it not clear to you that if any one shall invent a method of and an apparatus for transmitting light telegraphically he must necessarily cause the energy of light to set up electrical undulations similar in form to the light energy?

Ans. No.

Cross-Int. 98. If I understand your view of this case, it is enough for you to know that vocal or other sounds have been transmitted telegraphically to enable you to form a positive opinion that the method employed to accomplish that end is substantially the same as that method described in Bell's patent of '76, and that all inquiry as to the apparatus used and its mode of operation is entirely superfluous, unless, indeed, it be to confirm the opinion you have already formed: am I right?

Ans. It does not seem to me possible, as I have already said, to transmit articulate speech, or other sounds, with all their characteristics, except by the employment of the method invented by Mr. Bell, and I should therefore naturally and confidently expect, if I knew that such sounds had been transmitted telegraphically, to find that his method had been followed.

Cross-Int. 98½. I do not clearly understand your affidavits as to the use of currents in the Dolbear method. Do you agree with me that it is physically impossible for electric currents to have any effect whatever upon the Dolbear receiver, and also that it is physically impossible to operate the magnet receiver without electric currents.

Ans. I do not.

Cross-Int. 99. In the Dolbear method, is not the energy of the air waves used to control electrodes of a very short circuit of very little resistance, except that produced by the varying contact of the electrodes?

Ans. I do not understand exactly the nature of the distinction drawn in your question between what is styled the "Dolbear Method" and the specific methods of varying the resistance which are in very common use with all microphone transmitters when an induction coil is connected with them. The transmitter used by Prof. Dolbear, like the Blake transmitter as commonly used, has a primary circuit of low resistance, containing a microphone and battery.

Cross-Int. 100. Is there any description, suggestion or hint in either of the Bell patents of, *first*, any action of air waves upon an electrode, or, *second*, of any circuit only a few feet in length, or *third*, of any inductorium consisting of two helices, one in the primary and one in the secondary?

Ans. In the Bell patent No. 174,465, statements are made regarding the production of electrical undulations produced by a conducting wire electrode more or less deeply immersed in a liquid, and the statements of the patent are such as readily suggest the use of such a transmitter for the transmission of articulate speech. Nothing is said in the patents, as far as I notice, whether the circuit is long or short, and it must have been evident to Mr. Bell that his method was just as applicable to a short circuit as to a long one. Mr. Bell mentions the induction coil in his first patent, but without any reference to its use in connection with the telephone.

Cross-Int. 101. I do not think you have answered the first part of my question, as I am unable to see anything in Bell's patent of 1876 intimating or hinting at the vibrating of the conducting wire in mercury by the energy of air waves. Please answer that part of the question again with this explanation.

Ans. Mr. Bell does not specifically and in terms refer to the vibration of a conducting wire electrode by air waves. He does, however, describe the vibration of such a wire as one method of producing electrical undulations, and it seems to me that, taking this statement in connection with the construction and operation of the apparatus shown in Fig. 7, an intimation is given which is sufficient to lead any one possessing a knowledge of electricity and acoustics to see that such an apparatus might be substituted for the transmitter shown in Fig. 7; and, as a matter of fact, such an apparatus was constructed by Prof. Bell.

[*Adjourned.*]

BOSTON, June 13, 1883.

Cross-Int. 102. Is it your opinion that there is anything whatever in either of the Bell patents suggesting or hinting at the employment of a continuous voltaic current varied in strength by the energy of sound waves as a means of producing a series of vibratory currents?

Ans. In my answers to the last two questions I have stated that it seems to me that Mr. Bell indicates a means of producing a series of vibratory currents by the employment of a continuous voltaic current varied in strength by the energy of sound waves. Also the apparatus shown in Fig. 7 in the first Bell patent makes use of a continuous voltaic current, in which vibrations are set up by means of the energy of sound waves.

Cross-Int. 103. There is a continuous voltaic current indicated in Figs. 5, 6 and 7 of the Bell patent of 1876, but it is perfectly certain, isn't it, in Figs. 5 and 6, that the voltaic current is not intended to be altered by the energy of sound waves, and is intended to be altered by a blow upon the tuning fork of the transmitter or by setting that tuning fork in vibration in some other way than by the energy of sound waves? Do you assent to this?

Ans. The reeds shown in Figs. 5 and 6 may be set in vibration in various ways, — as by plucking with the finger, or by striking, or by wind. It is possible to set them into vibration by the energy of certain sound waves, though they are not well adapted to be set into vibration in this manner, and the tuned reeds could at best respond only to a very few different notes.

Cross-Int. 104. Does not the voltaic current in Figs. 5, 6 and 7 remain constant so far as the battery produces a constant current? and is it not entirely clear that the vibratory non-voltaic currents produced by the motion of the armature towards the magnet are in one direction, while those produced by the motion of the armature away from the magnet are in the other direction? In brief, that neither of the Figs. 5, 6 or 7 shows a continuous voltaic current varied by the energy of sound waves, but that all three of them show a continuous voltaic current practically constant with a series of vibratory non-voltaic currents in the same circuit produced by the motions of the armature?

Ans. The function of the battery in Figs. 5, 6 and 7 is to polarize or render magnetic cores of the electro-magnets. Your supposition, with regard to the direction of induced currents produced by the motion of the armature is correct. The current moving through the whole circuit is not a practically constant current, but a current which continually flows in a given direction, dependent upon the mode of connection of the battery with the circuit, which current sustains periodical variations in strength in correspondence with the motions of the armature of the transmitting instrument. The variations in current strength are evidently proportional to the velocity of the armature of the transmitter at any moment. We may consider the actual current produced as being equal to the algebraic sum of the positive current produced by the batterys and the positive and negative currents produced by the vibration of the armature of the transmitter. The vibrations of the armature in Fig. 7 are produced by the energy of sound waves, and in the sense in which I understood your one hundred and second question there is here described a mode of varying the strength of a continuous voltaic current by the energy of sound waves. The mode in which the energy of sound waves is made to vary the energy of the current in the voltaic circuit is by varying one of the sources of electro motive force present in that circuit.

In the sense which I have indicated in my answer, we may consider the current produced by the battery as practically constant, existing simultaneously in the line wire with other currents produced by the motions of the armature. As a matter of fact, considering the current produced by the battery at various instants of time, that current is not constant, since the induced currents themselves, in passing through the battery, cause its action to vary from instant to instant, although the average strength of the current produced by the battery may remain the same as if the induced currents were absent.

Cross-Int. 105. Do you think that induced currents produced by motion of an armature towards and from a magnet are voltaic currents?

Ans. That depends altogether upon the sense in which you use that term. The term "voltaic current," as generally used, is applied to a current produced by an ordinary voltaic battery. I think that where there exists in the same circuit as in that of Fig. 7 a strong current produced by a voltaic battery and a series of weak currents produced by induction, one might for the sake of brevity speak of the total current in the circuit as a varying voltaic current, though this use of language would perhaps be somewhat loose.

Cross-Int. 106. Bell speaks, in the 1876 patent, of sundry methods for producing undulatory currents: (1.) A wire through which a continuous current is passing caused to vibrate in the neighborhood of another wire. (2.) A cylinder with bar magnets rotating in front of an electro-magnet. (3.) Bringing the elements of a battery nearer together or farther apart. (4.) Immersing the conducting wire more or less in mercury or other liquid. (5.) Immersing the elements of the battery more or less in the liquid of the battery. Do you believe that there is anything whatever in the patent of 1876 suggesting or even hinting at the use of the energy of sound waves in either of these methods? I am aware that you have already partially answered this question in the affirmative, but I desire to put it all in one question so as to force upon your attention my view of the matter, which is that it is absurd to suppose that Bell had ever so much as even imagined the use of the energy of sound waves, so far as his 1876 patent enlightens us, except to set an armature in vibration before the poles of its magnet.

Ans. My view as to the absurdity of the supposition made is very different from that which you have stated to be your own. It seems to me that it would be strange, not to say absolutely absurd, to imagine that a man who had invented a method of transmission of vocal or other sounds telegraphically, as described in the patent, and who, realizing fully the various difficulties of an experimental nature which lay in the way to a practical solution of the question, saw clearly that undulatory currents must of necessity be used for the purpose of transmitting speech, and who had described various ways of producing electrical undulations, should not have seen, for example, that by the substitution for the armature and electro-magnet in the transmitter in Fig. 7 of a conducting wire attached to the membrane (placed horizontally) and dipping into a cup of conducting liquid, he could realize in theory, at least, a speaking telephone transmitter, by means of which the energy of sound waves could be used to produce electrical undulations.

Cross-Int. 107. I do not think that you have answered my question. Please reconsider it.

Ans. With regard to what the patent says on the subject, it seems to me that we have these various means described as general modes of producing electrical undulations in a continuous voltaic current. The patentee, having made these statements of the various ways in which such undulations can be produced, then goes on to say that in illustration of the method of creating electrical undulations, he will show and describe one form of apparatus for producing the effect. He then describes the specific forms of apparatus shown in Figs. 5, 6 and 7. I do not see that the fact that the specific form of speaking telephone which he describes makes use of the undulations caused in the voltaic current by the vibration of a body capable of inductive action limits him or any one else making use of the patent to this specific form of apparatus.

It seems to me that from what is said in the patent in view of the state of electrical and acoustical knowledge in 1876, any competent person would have seen that unless mechanical difficulties prevented, the additional methods pointed out by Mr. Bell for varying the strength of the current might any of them be used as alternative methods in the construction of a speaking telephone transmitter.

Cross-Int. 108. Take now the case of the cylinder with its bar magnets. Isn't it absurd to suppose that Mr. Bell intended to have that cylinder rotated by the energy of sound waves?

Ans. I do not suppose that Mr. Bell intended to rotate or vibrate such a cylinder by the energy of sound waves. He probably referred to it as a simple illustration of the production of such a current in well-known apparatus. Any competent person would see that though a cylinder with bar magnets might possibly be made to form the transmitter of a speaking telephone, yet that such a device would be an impractical one, so far as efficiency was concerned. It is quite the contrary, however, with some of the other devices suggested in the patent.

Cross-Int. 109. Isn't it also absurd to endeavor to make a transmitter by vibrating the conducting wire in mercury by energy of air waves?

Ans. Quite the contrary. Very good transmitters have been made by vibrating the conducting rod or wire in mercury.

Cross-Int. 110. What was the rod or wire referred to made of?

Ans. In one form, which I have in mind, a little rod of carbon was used.

Cross-Int. 111. I have got the idea from your present deposition that you think that the Dolbear method infringes the Bell patent of '76 because of the use of a voltaic current with the transmitter. Am I right about that?

Ans. I do not recollect at what place in my deposition I have made any allusion to the legal matter of infringement, or where I have said that the chief similarity between the mode of operation of the Dolbear apparatus and the Bell apparatus is that they both use a voltaic current with the transmitter, although they unquestionably do have this similarity. I do not know that I fully understand the question, but I certainly do not think that if Prof. Dolbear was to substitute a thermo-electric battery, or if possible, a perfectly steady current from a dynamo machine for the voltaic battery in his apparatus, that this would in any way affect the substantial similarities which I have explained to exist between the apparatus and method of the Bell patent, and the apparatus and method used by Prof. Dolbear.

Cross-Int. 112. Do you agree with me that the electrical undulations in the secondary coil and the line and the plates of the receiver in the Dolbear apparatus are radically different from anything described, suggested or even hinted at in either of the Bell patents in suit?

Ans. I do not; on the contrary, I know that the nature of the electrical undulations in the coil and the line wire in the Dolbear apparatus is the same as, and can in no way be distinguished from the nature of the electrical undulations in the magnet coils and the line wire of the Bell apparatus of Fig. 7. In the fifth claim of the first Bell patent no specific kind of electrical undulations are referred to, as I have already said, on p. 13 of my affidavit in reply. The only essential thing is that the electrical undulations shall be similar in form to the sound waves producing them.

Cross-Int. 113. You have pointed out that the general laws of attraction are true of both the Bell and Dolbear receivers. Is not the attraction of gravitation also inversely as the square of the distance?

Ans. The mutual attraction of two gravitating particles is inversely as the square of the distance between them, and directly as the product of their masses.

Cross-Int. 114. In your affidavit something is said about the practical use of variations of charge or electrical attraction, especially on page 46 of your first affidavit. Do you know of any practical application, scientific or useful, of electricity before 1880, except of currents of electricity, or what is called in Bell's '76 patent dynamical electricity, and in which the effects were produced by the flowing of the current through a helix to produce magnetic effect, or an electrolytic compound to produce chemical effects, or a conductor to produce heat effects, or animal tissue for physiological effects? I quote my question mainly from the affidavit of Prof. Trowbridge, which please consider, and if you differ from any of his statements, please state wherein.

[*Complainants object that the word "dynamical" is used by Mr. Bell in his patent to express that the armature is to be of a material which would serve to produce electrical effects as an inducing armature or core in a dynamo machine, and that the question attributes to it an entirely different meaning.*]

Ans. I have mentioned in my affidavits certain forms of apparatus which do not make use of a current of electricity flowing through the helix, or producing effects in the ways which you have specified. Among these the use of condensers operated by varying charges of electricity in connection with sub-main telegraphy is of the widest application and utmost value. As another instance, I will mention Mr. Varley's musical telegraph, patented in 1870, which is a practically operative apparatus. I had, among other forms of apparatus, both of these in mind when making my first affidavit, and I have referred to them specifically in my later affidavit.

[*Adjourned.*]

BOSTON, June 14, 1883.

Cross-Int. 115. Please answer again Cross-Int. 102, and to make the question clearer than it seems to have been to you, I will state that it refers to the primary current used in the commercial telephones, and the vibratory induced currents produced by variations in the magnetic energy of the transmitter core in such telephones.

Ans. There is in neither of the Bell patents any reference to the use of an induction coil in connection with the telephone.

Cross-Int. 116. Your answer is limited to apparatus, while I meant my question to include both method and apparatus. I will therefore repeat my question in a more limited form, as follows: Is that method of transmitting speech which consists in transforming the energy of air waves into variations of resistance of a voltaic circuit and thereby into variations of current in that circuit, transforming those current variations into magnetic variations and those into variations of current strength, and these latter into magnetic variations, described, suggested or in any way hinted at in either of the Bell patents in suit?

Ans. The specific way of using the method invented by Mr. Bell stated in your question is not referred to in the Bell patents. The use of an induction coil in connection with the transmission of signals by circuit-breaking apparatus was, however, well known at the date of the patent.

Cross-Int. 117. It seems to me that the way of accomplishing a certain end, the manner of accomplishing a certain end, the method of accomplishing a certain end, and the process, mode or system by which a certain end is accomplished are for all practical purposes synonymous terms. Do you agree with me as to this? If not, do you think the success of the complainants in this case depends in any way upon the careful selection of terms?

Ans. Some of the terms that you have mentioned may often be used with propriety as synonymous, but I do not think they are always synonymous. I suppose that the success of complainants in this case must depend upon the validity of their claims rather than upon any particular nomenclature which they may adopt. So far as I am concerned as a witness I have simply endeavored to choose such terms and to use such language as should make the meaning of my statements clear and free from liability to be misunderstood.

Cross-Int. 118. It seems to me very clear from Bell's 1876 patent that the method of transmitting sounds telegraphically therein described consists essentially in the following steps: (1) Transforming the energy of sound waves into magnetic energy; (2) that into vibratory electric currents; (3) and those into magnetic energy, and by that producing sound waves which are as like the first as the perfection of the transformations admit of; that is to say, if all the energy of the initial sound waves be transformed without waste into magnetic energy, and so on, each transformation being complete and without waste, then the transmission would be perfect. Do you agree with me as to this?

Ans. I do not. Mr. Bell's claim is for both method and apparatus for transmitting vocal or other sounds telegraphically by causing electrical undulations similar in form to the vibrations of air accompanying the said vocal or other sounds. In his reference to the particular form of apparatus in which occurs the successive series of operations referred to in your question in the body of the specification, Mr. Bell says that as an illustration of the method of creating electrical undulations he will show and describe one form of apparatus for producing the effect.

Cross-Int. 119. Do you not see clearly that the undulations referred to in that part of the specification to which you have just referred are not and are not intended to be similar in form to any air vibrations?

Ans. This is not at all clear to me. Mr. Bell first describes in illustration of the method and apparatus in which electrical undulations are produced by the vibrating armature which he says can be set in vibration in a variety of ways, as, for example, by wind. A little later he says that another mode by which the armature may be set in vibration is that shown in Fig. 7, whereby motion can be imparted to the armature by the human voice or by a musical instrument. So far as the electrical undulations are concerned, the form of apparatus shown in Fig. 7 is similar to that shown in Fig. 5, but the mode by which motion is imparted to the armature in Fig. 7 is entirely different from any of the modes intended to be used with the apparatus of Fig. 5, since the apparatus of Fig. 7 is a speaking telephone.

Cross-Int. 120. You do think, do you not, that the method described in Cross-Int. 118 is described and illustrated by Fig. 7 in Bell's patent of 1876, and also clearly described and more fully illustrated in Bell's patent of 1877?

[*Complainants object to the question, first, because it calls for an opinion on the legal construction of the patent and claim; second, because it assumes to narrow the meaning of the term "method" as employed in the patent and claim, so that it shall apply to only one particular form of apparatus out of many by which the method may be practised.*]

Ans. The changes which you have described unquestionably take place, and in the patents are described as taking place, both in the apparatus of Fig. 7 and in certain forms of the apparatus described in the second Bell patent.

Cross-Int. 121. Is not the method, or, if you prefer the term, the *specific method* described in Cross-Int. 118 a noble invention of the very highest rank, in your opinion?

[*Same objection, and the further objection that what constitutes the "method" of the patent is specifically described in the claim, and not limited to the form of apparatus which performs the precise transformations referred to in the question.*

Defendants' counsel adds to the question in view of the objection.]

I do not refer to any apparatus, either in the one hundred and eighteenth or in the present question.

Ans. There is no doubt that had the invention of Mr. Bell been no broader than that referred to in your question, it would still have been a noble one.

Cross-Int. 122. Will you explain what you believe to be the differences between a current of electricity in a closed circuit, whether of a continuous wire connecting the poles of the generator, or a circuit in which one pole of the generator is connected to earth by one wire, and the other pole connected to earth by another wire, and what is sometimes called a current of charge, that is, where the poles of the generator are not connected by an electrical conductor?

Ans. In the first case, if we use a constant source of electricity, other things remaining unchanged, we shall have a steady, permanent current flowing indefinitely through the whole circuit.

In the second case, it is impossible to obtain such a steady, permanent current. The current will flow through the line from the source of electricity to the farther end, but as the line and condenser or other apparatus at the farther end become more and more fully charged, the current will diminish in strength, and will finally cease altogether when the potential of the whole line and connected apparatus at the farther end is the same as the potential of the body furnishing the supply of electricity. That is, in this case the current line, and connected apparatus and greater in proportion as the capacity is greater.

In these statements I have assumed that the line is so connected with the source of electricity that the current flows from the source into the line, that is, that the potential of the source is at the beginning of the operation higher than the potential of the line and connected apparatus.

Cross-Int. 123. You have twice in your deposition had your attention called to a conducting wire vibrating in mercury. Do you believe it possible to make a transmitter capable of use in the transmission of vocal or other sounds in which there shall be a wire — I don't mean a carbon rod — vibrated in mercury by the energy of air waves?

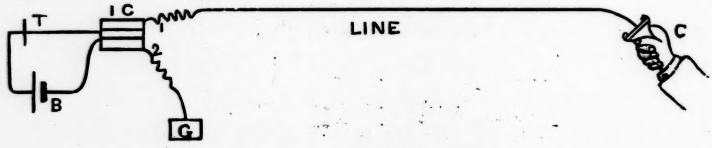
Ans. I have not experimented with such an instrument, and do not know what has been done by others using mercury in the manner referred to in your question. The conditions are not very favorable for the transmission of speech with such a transmitter, but I do not feel ready to say that I believe it to be impossible. It seems to me that in certain ways I might be able to succeed in doing this, though I am not at all certain.

Redirect Examination.

Int. 124. I infer from your last answer that the apparatus indicated in the question would theoretically perform the kind of operation and produce the kind of electrical undulations appropriate for speech, but that your doubt is whether the conditions of that particular choice of construction and materials would be favorable enough for practical efficiency. Is that your meaning; and if not, what is it?

Ans. Your inference is entirely correct. The only question in my mind was as to whether the variations in resistance, which would be produced by a conducting wire, by which I understood a wire of metal vibrating in mercury, would be sufficiently great to produce electrical undulations strong enough to be received with a telephore receiver.

Int. 125. In your answer to the Cross-Int. 122, you assumed the case of a constant source of electricity and you assumed that it acted upon a conductor for an indefinite time, so that the current in the case of the condenser was limited in the duration of its flow merely by the capacity of the line and the connected apparatus. I now wish to call your attention to an apparatus such as is shown in the following figure: —

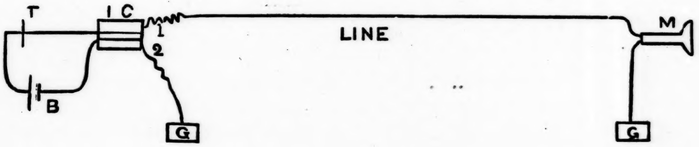


which is the same as Fig. 2 of your affidavit. You may assume that the transmitter T is a microphone transmitter substantially like the Dolbear microphone transmitter, and is actuated by the utterance of words against the plate, and that the receiver is a Dolbear receiver. Will you please state whether with this arrangement, and so long as the speaking goes on, currents continue to flow to and fro between the terminal 1 of the coil and the connected plate of the receiver? And if so, state whether the variable character of the source of electricity has anything to do with that continuance, and what.

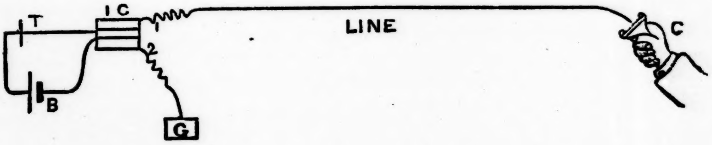
Ans. In the apparatus shown in the figure undulatory currents flow to and fro through the line wire so long as the transmitter is actuated by the voice. It is by the passage of these undulatory currents from the terminal of the coil to the front plate of the condenser receiver that the receiver becomes charged to a greater or less extent and is thus able to reproduce speech. The undulatory currents in the line wire are in their nature the same as though a ring or complete wire circuit were used. The differences which are presented are of no substantial importance in the reproduction of speech, being mere differences of amplitude and perhaps of phase of the undulations. It is because of the varying strength of the source of electricity, that is, the varying strength of the current flowing through the induction coil, that there is a continuance in the flow of the to-and-fro-undulatory currents in the line wire, since, because of the alternate changes in direction in the undulatory currents the condenser is completely discharged a great many times in each second and never acquires the maximum charge of which it is capable; that is, while it is impossible with a constant source of electricity to produce a continuous current in the line wire of such an apparatus, with a variable source of electricity, currents will continue to flow to and fro as long as the variations in the strength of the source of electricity are kept up.

[*Noon recess.*]

Int. 126.—Please consider the ordinary arrangement of the microphone transmitter and magneto receiver as shown in the following figure: —



which is the same as Fig. 1 of your affidavit, and the microphone transmitter and Dolbear condenser receiver, which is the same as Fig. 2 of your affidavit,



and state what electrical changes take place in primary circuit, induction coil and line wire, Fig. 1, when the transmitter T is spoken to, and then state the electrical changes which take place in the primary circuit, induction coil and line wire in Fig. 2, when the same sounds fall upon its transmitter, and compare the electrical changes which are thus set up in the two with particular reference to that character of succession of the electrical variations in each part which is referred to in the fifth claim of the first Bell patent, and there characterized as electrical undulations similar in form to the sound waves.

Ans. In the primary circuit of the induction coil in Fig. 1, there is placed a voltaic battery B and a microphone transmitter T. When the transmitter T is acted upon by the sound waves produced by the voice, the strength of the battery current is caused to vary in correspondence with these sound waves, so that electrical undulations are produced in the primary circuit of the coil, which undulations are similar in form to the sound waves producing them. Each variation in the strength of the current in the primary circuit of the coil will (in accordance with the well-known principles on which the induction coil is based) cause a change in the potential of the terminal of the secondary helix, — as I have already explained on page 9 of my affidavit in reply.

For convenience' sake, I will consider only that terminal 1 of the coil to which the line wire is attached. The action of the transmitter will be such as to raise or lower in varying degrees the terminal 1 of the coil. If the terminal 1 has its potential raised above that of the line wire and connected apparatus, a flow of electricity will take place through the line wire and receiving instrument to the earth. If the potential of 1 is lowered, then a flow of electricity takes place from the earth through the receiving instrument and line wire to the terminal of the coil. The more rapid the rise or fall of potential of 1 the stronger will be the current in the line wire toward the farther end of the line or in the opposite direction, according as the potential of 1 is raised or lowered. The violence of this flow is determined by the rapidity of change of the potential of 1, and the changes of potential of 1 are determined by and proportional to the changes in the current in the primary of the induction coil, but owing to the mode in which the transmitter acts the electrical undulations in the primary circuit are similar in form to the sound waves producing them. This same similarity therefore holds for the currents within the secondary helix of the coil and for the changes in potential of the terminal 1, so that the electrical undulations produced in the line wire are similar in form to the sound waves producing them.

In Fig. 2 the changes which take place in the primary circuit of the induction coil are identical with those taking place in the corresponding part of the apparatus of Fig. 1. Hence when the transmitter is in operation the terminal 1 of the induction coil has its potential raised or lowered in correspondence with the variations in the sound waves actuating the transmitter. When the potential of the terminal 1 is raised, a flow of electricity is produced in the line wire from 1 to the farther end of the line at C. If the potential of 1 is lowered, a flow of electricity is determined through the line wire from its farther end towards 1. The violence of the flow or strength of the current in either case is determined by the amount of the rise or fall in the potential of the terminal 1; so that when the transmitter is actuated by the voice, there are produced in the line wire electrical undulations similar in form to the sound waves producing them, that is, in Fig. 2, as in Fig. 1, there is a flow of electricity to and fro in the line wire, which varying flow constitutes the electrical undulations.

Int. 127. As I understand your last answer it is true, in Fig. 1 and Fig. 2, that the varying motions of the transmitter diaphragm, vibrating under the influence of sound, produce in the primary circuit variations of flow, similar in form to the air motions in the sense in which that phrase has been used, and by means of these produce at the terminal 1, for example, variations of potential having the same similarity of form, and by means of these variations of potential of terminal 1, produce between that terminal and the distant point to which it is electrically connected and through all intermediate conductors, a transference or flow of electricity which is not uniform, but the variations of which are again similar in form to the preceding variations mentioned.

Am I correct in this; and if I am, please state whether the fact that there is a flow in the primary circuit, in the body of the secondary coil and in the connected conductor, and the fact that the flow in these various parts and the accompanying changes of potential are similar in form to the actuating sound waves, have been learned by you from purely theoretical consideration or from actual experiment, or both.

Ans. Your understanding of my answer is correct. I have learned it from both. I know on purely theoretical grounds that in the primary circuit, throughout the whole secondary coil and in the line wire a flow of electricity occurs as I have described, so that its variations are similar in form to the actuating sound waves, but I have also proved this in the most complete manner by the experiments which I have described in my affidavit in reply. I find that if a magneto telephone receiver is placed in the primary circuit, in any part of the secondary helix of the induction coil, or in any part of the line wire, the speech which is uttered into the transmitter T will be reproduced by the receiver. The fact that the receiver does thus reproduce speech shows most conclusively that there are electrical undulations in that part of the circuit in which it is placed, and that these electrical undulations are similar in form to the sound waves producing them, and also that the nature of the electrical energy present in that part of the circuit is such as to be adapted to operate such a magneto receiver.

Int. 128. It has appeared that the motions of the free plate of Mr. Dolbear's receiver which give rise to the sound heard by the listener are due to the variations in the attraction between it and the back plate, and that the character of those motions which determine the character or quality of the sound is due to the character of these variations in attraction which take place from instant to instant. Do you or do you not agree with this view?

Ans. The variation in attraction between the two plates is the most obvious, though perhaps not the complete explanation of the motions which occur. It is undoubtedly a fact that the character of those motions which determine the character or quality of the sound is due to the character of the variations taking place from instant to instant in the amount of electricity on the free plate of the condenser (which is the one connected with the line), and, so far as attraction is the chief or only cause, to the character of the variations in the attraction.

Int. 129. Is the amount and direction of electricity present from instant to instant in the free plate of the condenser in any way affected by or dependent upon the flow in the line wire which you have just described, and does the character of the changes which take place in the amount of electricity in the free plate of the con denser in any way depend upon or correspond to the changes in the flow which takes place in the line wire which you have described?

Ans. The electricity which is present from instant to instant on the free plate of the condenser is immediately dependent upon and determined by the flow in the line wire. The amount is increased when the flow in the line wire is toward the condenser, and diminished when the flow is away from the condenser. This increase or diminution depends upon and corresponds to the changes which I have described as taking place in the flow of electricity in the line wire.

Int. 130. Are these changes in the amount of electricity in the free plate of the receiver discontinuous in their character or are they undulatory; and if the latter, do their successive changes correspond in any way to the successive changes which take place in the air during the utterance of the sound which at the moment actuates the transmitter?

Ans. The changes referred to are undulatory in their character, corresponding, as I have already said, to the changes in the flow of electricity in the line wire, and hence correspond, and are similar in form to the successive changes which take place in the air waves actuating the transmitter.

Int. 131. Is this similarity in form mentioned in your last answer important for the transmission of speech by the Dolbear apparatus; and if so, how important?

Ans. The similarity is all important, and it would be absolutely impossible for the Dolbear apparatus to transmit speech if this similarity did not exist.

Int. 132. It appears, then, that in every part of the Dolbear apparatus where electricity is active it undergoes a series of changes of strength in consequence of the action of the voice upon the transmitter, and that the series of changes which it undergoes in each part of the apparatus, being changes of flow, of potential, of charge, or of several of these together (according to their respective parts), are undulatory in their character and correspond in their undulations to the air motions. Will you now state whether it is important for the transmission of speech by the Dolbear apparatus that these variations should be undulatory instead of intermittent, and that their undulations should always be of the special form which are indicated by the fifth claim of the patent as similar to the sound waves which constitute the sounds being transmitted at the instant; and if so, how important is it that there should be this similarity?

Ans. It would be impossible to transmit speech by the Dolbear apparatus if the variations were not undulatory as distinguished from intermittent variations. It is also necessary for the transmission of speech that these undulations existing in every electrically active part of the Dolbear apparatus shall be similar in form to the air waves which constitute the sounds being transmitted in the sense in which that term is used in the fifth claim of the first Bell patent.

Int. 133. State whether you do or do not find in any of the publications which have been put in evidence any indication that the various writers, or the persons whose ideas they profess to report, sought to produce, or conceived that it was desirable to produce, by any means or in any part of their respective instruments, electrical undulations similar in form to the sound waves constituting the sound sought to be transmitted, or even electrical undulations of any form as distinguished from electrical intermittences.

Ans. I do not find in any of the publications referred to any indication whatever that it was supposed by any one that it was desirable to produce electrical undulations rather than electrical intermittences, still less that it was desirable to produce electrical undulations similar in form to the sound waves constituting the sound to be transmitted.

Int. 134. What kind of variations do those publications show that the writers and experimenters directed their care to the production of and believed they had produced?

Ans. Intermittences.

Int. 135. In the attempts which you have made to transmit speech by the Reis apparatus, what care did you take to secure favorable conditions, and what success did you have? State how much you ever transmitted with it.

Ans. I have several times tried to transmit speech by means of the Reis apparatus. In the last and most successful experiments which I made, I took every precaution that I could think of to secure success. The transmitter and receiver were in separate rooms in the same building, the receiver was in a room which was absolutely quiet, the receiving and transmitting rooms were connected together by a tell-tale line furnished with speaking telephones. The time chosen was a holiday and the building was closed. No one was in the rooms except those taking part in the experiments, and absolute quiet was secured.

Anything which I thought that I heard with the Reis apparatus was transmitted by the tell-tale line to the transmitting room, and the words which were actually spoken into the Reis transmitter were transmitted to me through the tell-tale line. The speaker at the transmitting end was a person accustomed to the use of all kinds of telephonic apparatus, with whose voice I was perfectly familiar. He was requested to speak with as great loudness as was consistent with a preservation of the unbroken contact between the electrodes of the transmitter, and from time to time he was communicated with through the tell-tale line, that he might speak louder, or less loud, as the experiment seemed to require. I listened very carefully at the receiving instrument, and several times thought that I understood short sentences which were transmitted, but found on inquiry through the tell-tale line that I was mistaken. The only sentence which I heard correctly was one which had invariably been used by the same speaker in testing different kinds of telephones with me, and which I could recognize even by its rhythm. The sentence was, "The sun is shining brightly," which was actually the case at the time.

I was at the time that it came conscious that its rhythm as much as anything else enabled me to recognize it. I also recognized the clause, "It is half-past ——." The sentence spoken into the transmitter being, "It is half-past five."

This was also a sentence which it was customary for the speaker to use with me as a listener in testing telephones, and here again the rhythm was a sufficient indication of the sentence to enable me to recognize all except the last word. This was all I succeeded in recognizing, although the experiment lasted about an hour. In my experience in testing telephones, — the efficiency of telephone transmitters and receivers, — I have not felt at liberty to rely on the recognition of familiar and frequently repeated sentences, since it is easy to recognize such sentences from rhythm alone, although there is no proper articulation.

Int. 136. Will you state how nearly the Reis apparatus used by you on this occasion resembled defendants' Exhibits Reis Transmitter and Reis Receiver No. 1, particularly as regards size of diaphragm, and material and weight of hopping piece of the transmitter?

Ans. The Reis apparatus used by me was as perfect a reproduction as possible of the defendants' Exhibits Reis Transmitter and Reis Receiver No. 1. The only differences that I could find were that the reproduced receiver did not have some of the cracks which were present in the Exhibit Receiver, and that the wood of which the apparatus was made was of a different material.

BOSTON, June 15, 1883.

Int. 137. In Mr. Dolbear's deposition, page 389, and again in his answer 182, page 473, and in the last paragraph of Mr. Buck's answer No. 2, pages 476, 477, reference is made to a phenomenon which takes place in a conductor like that of Dolbear's apparatus, at one end of which is a source of electrical energy, and at the other end of which is a condenser plate, and this phenomenon is described as the filling up of the condenser plate and line by the electricity furnished by the generator, which diminishes the difference of potential between the sending end and the receiving end, and thereby diminishes the current on the line. Those witnesses have undertaken to represent that phenomenon and its effects by an expression which they have called B_3, and which they have introduced into the denominator of the fraction by which they express the current strength in the Dolbear apparatus at each particular moment. Will you state the nature of the phenomenon to which they refer?

State whether it is proper to represent it by a factor introduced into the denominator of the fraction representing the current strength. State whether it deprives the undulations of current or the other electrical undulations in the apparatus of their similarity to the sound waves, or whether its effect is to diminish the amplitude of the variations without depriving them of that similarity of form which you have frequently described and specially referred to in your answers 125–133, inclusive.

Ans. The phenomenon referred to is due to the fact that when a condenser is connected with a source of electricity the magnitude of the current flowing into the condenser from the source is determined by the difference of potential between the source and that terminal of the condenser to which the line wire is attached. As the current flows into the condenser plate this becomes more and more strongly charged, its potential rising higher and higher as more electricity enters it. The difference of potential between the source and the condenser plate therefore diminishes as the charge of the condenser decreases, and since the strength of the current of electricity is dependent upon the difference of potential between the source and condenser plate, this strength will diminish as the charge of the condenser increases, until it becomes zero, when the condenser plate has assumed the same potential as the source of electricity.

The amount by which the action that I have just described will affect the strength of the current flowing into the condenser will depend upon the capacity of the condenser, upon the original difference of potential between the source of electricity and the condenser plate, and the time which has elapsed since the beginning of the flow of electricity from the source into the condenser plate. In proportion as the capacity of the condenser is greater, and the time during which the current flows less (other things remaining the same), the magnitude of the effect under consideration will be less. From what I have said it will be clear that this phenomenon has no relation to an increase of resistance, but is really a diminution of the difference of potential between the two ends of the line wire, and hence causes the value of the term E in the numerator of the fraction to be less than it would otherwise be.

Hence, so far as the effect which I am considering enters practically into the operation of the Dolbear condenser receiver, it should be represented by quantity subtracted from the term E in the numerator of the formula. Represented thus, the formula considered as applying at the particular moment under consideration would give simply a diminished value to the current C. The way in which this quantity (represented in Prof. Dolbear's formula by B_3) varies is such as simply to mitigate the violence of the flow of electricity in the line wire, thus diminishing the amplitude of the electrical undulations, but not depriving them of their substantial similarity in form to the sound waves producing them. That the substantial similarity in form is unaltered by the phenomenon under consideration is shown experimentally in the most perfect manner by the fact that both the condenser receiver and a magneto receiver, placed in the line wire between the terminal of the induction coil and the receiver, are capable of clearly reproducing articulate speech.

Int. 138. In several of the Reis publications the peculiar tone or sound produced at the Reis receiver is noticed. Thus Pisko states (record, page 586):—

"Its strength not very remarkable, and its clang [quality] buzzing, like that of a weak-sounding reed-pipe, something like a child's trumpet."

Kuhn, record, page 598, says:—

"The quality of the sounds thus produced is not pleasant. They are almost like the sounds of toy trumpets at times, also like the buzz of a fly caught in a spider's web, and the like."

Dr. Van der Weyde, page 609, says:—

"The receiving instrument in fact sings the melodies transmitted, as it were, with its own voice, resembling the humming of an insect, regardless of the quality of the tone which produces the original tune at the other end of the wire."

Will you state whether in using the Reis apparatus you have observed this characteristic buzzing sound at the receiver, and whether it is due to a circuit-breaking action or to a microphonic action of the transmitter?

Ans. I have frequently noticed the buzzing sound, which is very marked and peculiar, resembling almost exactly the buzzing of a fly, and it is produced only when the transmitter is so operated as to make and break the circuit.

The quality of sounds transmitted microphonically is quite different. I have tried the experiment of having the person at the Reis transmitter sing a single prolonged note into it, at first very gently, so as not to break the circuit, then more loudly, so that the circuit was broken at each vibration of the membrane. I could always tell the moment at which microphonic transmission of the sound ceased, and transmission of the pitch alone by the action of the transmitter as a circuit-breaker began, by the sudden change of the quality of the sound heard at the receiver, this peculiar buzzing quality appearing immediately upon the beginning of the breaking of the circuit by the transmitter.

Int. 139. In that experiment could you tell by the relative loudness of the sounds when the microphonic action ceased and the circuit breaking began, and how marked was the difference?

Ans. The loudness of the sound is far greater when the circuit is broken than when the sound is transmitted microphonically. In the latter case I could only hear the sound by placing my ear closely against the receiving instrument, whereas, in the former case, the sounds produced by the receiver were loud enough to be distinctly audible throughout a very large room.

Int. 140. In your fifty-first cross-answer, page 508, you have stated that while the circuit is being made and broken at each vibration of the membrane, some slight electrical undulations might possibly be produced during the brief instant when the electrodes were in contact between two successive interruptions. Will you state whether such fragmentary interruptions which can thus be produced would give an effective undulatory character to the current, as a whole, or whether they would be overshadowed and their possible theoretical effects overpowered by intervening interruptions?

Ans. The interruptions are so frequent and the sound due to them so loud that the minute effects referred to in my fifty-first answer would be entirely overpowered, and it would be practically impossible for them to give any undulatory character to the current as a whole. Whatever minute undulations might be produced would be entirely devoid of practical value, even if they could be observed at all.

Int. 141. Were circuit-breakers (by which I mean devices which absolutely broke off the current and then let it flow again while alternately opening and closing the circuit) known to and in use by electricians in 1860; and if so, will you state whether the phrase used in the German publications relating to Reis, to characterize his apparatus and the operations which he performed, was the same as that technically applied to other circuit-breakers?

Ans. Circuit-breakers were constantly employed by electricians at the date mentioned. The phrase by which the apparatus and operation of the Reis transmitter are designated are the same as those technically applied to other forms of circuit-breaker; thus, in the Reis lecture as published by Reis, on page 542, I find among others the following expressions, of which I give both the English and the German: "In this way each sound wave causes a breaking and closing [ein Oeffnen und ein Schliessen] of the current [Stromes]. . . . On breaking the circuit [beim emterbrechen des Stromes] these atoms seek to regain their position of equilibrium." . . . "This is the case if the making and breaking of the current [Unterbrechungen und Schliessungen des Stromes] occur with comparative slowness." . . .

"The iron wire no longer gives its longitudinal (normal) tone, but a tone whose pitch corresponds to the number of interruptions [Unterbrechungen] (in a given time); this is the same as saying that *the rod reproduces the tone* [*ton*] *impressed upon the interrupter* [*dem Unterbrechungs apparat*]."

In Kuhn's description of Reis, page 393 of the record, the term "Unterbrecher" is applied to a well-known form of circuit-breaker. "Yet the possibility cannot be controverted that the principle of

Neef's circuit-breaker [Unterbrecher] might contribute to the solution of the problem in question."

On page 594 the same term is repeated.

In Müller-Pouillet's description of Reis, page 603 of the record, I find an ordinary circuit-breaker is denominated by the same term (Unterbrechungs apparant) that is applied a few lines below to the Reis transmitter.

The term "unterbrechung" is the ordinary term technically used to indicate the breaking of the circuit, and the term "unterbrecher" or "unterbrechungs-apparat" is a technical designation of a circuit-breaker. It never has any other meaning than this.

Int. 142. Is the book of Kuhn, which you have just referred to, a standard work of recognized authority or not?

Ans. It is a standard work, and was the best work in German upon the subjects of which it treats at the date of its publication, in 1866.

Re-cross Examination.

Cross-Int. 143. Suppose the poles of a battery to be joined by a wire, and describe the current which ensues, especially as to the efforts of the battery to charge one pole positively and the other negatively, in conflict with the tendency of the electricity generated by the battery to discharge itself, by reason of the presence of a conductor joining its poles.

Ans. In the case supposed there is a certain difference of potential between the poles of the battery, that is, between the ends of the wire by which the poles are joined. This difference of potential depends upon the battery used, but for a given battery we may, for the purposes of this explanation, consider it to be constant. Owing to this difference of potential between the two ends of the wire a steady current flows through the wire, the magnitude or strength of this current being indicated by the familiar equation $C = \frac{E}{R}$. Since, owing to the action of the battery, the difference of potential between the two ends of the wire, which constitutes the electromotive force, is constant, and since the resistance of the wire is constant, the current will also be constant.

Cross-Int. 144. You should have added after the words "battery used" the words "and the resistance of the conductor," should you not?

Ans. No.

Cross-Int. 145. Now take the case of a tank of water with a pump in it instead of a battery, and a pipe leading from the pump chamber back into the tank in place of the conductor, and liken the connection of the conducting pipe and the pump chamber to the positive pole, and that end of the pipe which discharges into the tank to the negative pole, and suppose the pump to be driven by a practically constant power, will not the head or pressure of the water at the place I have likened to the positive pole depend upon two things — first, the power of the pump, which I liken to the electro-motive force of the battery, and secondly, upon the resistance offered to the current through the conducting pipe which I have likened to the conductor; and will not the strength of the current of the water depend on the difference between its head or pressure at the place I have likened to the positive pole, and the head or pressure at the place I have likened to the negative pole; and would not the analogy be exact if water were one form of energy instead of one form of matter?

Ans. So far as the head of the water and the strength of the current of water produced are concerned, the views implied in your question are correct. I have no means of knowing what physical laws water would follow if, instead of being water, it were something else which might and would possess properties and follow laws entirely different from those which the substance water does and must follow. If, as I infer from your question, you consider your analogy as stated to be applicable with any strictness to electricity and its laws, you are entirely incorrect, since the quantitative laws are entirely different in the two cases, and it is only when considering the question qualitatively and in a very general way that these hydrostatical and hydro-dynamical analogies can safely be relied upon; still more, some of the suppositions which you make with regard to the water and the pump are quite different from the conditions which are present in the voltaic battery.

Cross-Int. 146. Several times in the course of this deposition I have been compelled to infer, and more especially by your answer to Cross-Int. 144, that you were of the opinion that the electric conditions of the positive and negative poles of a battery or other generator of electricity depended solely upon what is called the electro-motive force of the battery or other generator, and not at all upon the presence or absence of a conductor joining these two poles, or upon the resistance of that conductor. Do you believe that the presence or absence of the external conductor, or the resistance of that conductor, has nothing to do with the electric conditions of the poles of the generator, or can you explain how electric pressure, or head, or tension, or potential can exist and differ widely at the poles of the generator when those poles are joined by a conductor of trifling resistance?

Ans. In my one hundred and forty-fourth answer I stated the fact which is well known to be true for a voltaic battery, and which must be true, since Ohm's law applies to a circuit consisting of a battery and conducting wire.

A simple illustration will show this to be a fact. Let us suppose that a given battery has its terminals joined by a copper wire, and let us measure the current flowing in the circuit. Now let us increase the resistance of the conducting wire by lengthening the wire until the total resistance in the circuit is twice what it was before. As a matter of fact we shall find that the current is only one half as great, that is, the current is reduced in direct proportion to the resistance added; and this shows that the electro-motive force in the circuit must be the same in both cases, since according to Ohm's law, if the electro-motive force changed on doubling the resistance in the circuit the current would no longer be just half as great.

In the case of transient or rapidly varying currents, such as we have with an induction coil, the resistance of the conductor has a very great effect upon the electrical condition of the terminals of the coil.

The resistance of a conductor is simply the constant relation which we find to exist with a steady current between the electro-motive force in the circuit and the current produced by that electro-motive force; that is, since $C=\frac{E}{R}$, $R=\frac{E}{C}$. The electrical resistance of a wire, if we suppose no heating to be produced by the current, is independent of the strength of that current. It is difficult to explain every point concerned in the production of a voltaic current while there is so much obscurity regarding certain matters as at present. Perhaps the clearest explanation that I can give of the possibility of a considerable difference of potentials existing at opposite ends of a wire of slight resistance is, that the less the resistance of the circuit and the stronger the current the greater will be the chemical action in the battery cells; or using your own analogy of the pump (Cross-Int. 145), the pump, instead of being driven by a practically constant power, will be driven by a power which is greater in proportion as the amount of water raised, *i. e.*, the strength of the water current is greater. The increased consumption of zinc in the voltaic battery when the resistance is diminished may be considered as acting to keep up the electro-motive force.

Cross-Int. 147. If of two insulated masses of metal one be electrified, as is the positive pole of a battery or other generator, and the other as is the negative pole of that generator, and the two thereafter joined by a conductor, both will cease to be electrified, will they not, after a very brief interval of time?

Ans. Assuming, as I understand, that your question does, that the masses of metal bear exactly equal charges, of opposite signs, this will be the case.

Cross-Int. 148. Precisely that is what happens when you join the positive and negative poles of a generator by a conductor, except that the electrified condition of the poles is kept up by the generator, and therefore the discharge from the positive to the negative pole is continued as long as the generator keeps up its supplies of electricity?

Ans. That is the case.

Cross-Int. 149. In the case of the two insulated masses, what is the difference in the current of discharge, whether they be joined by a short, stout copper wire of trifling resistance, or by a long, fine copper wire of, say, one hundred times the resistance of the first wire?

Ans. In the case of the wire of high resistance the discharge will occupy a longer time than when the resistance is lower.

Cross-Int. 150. But obviously the quantity of electricity flowing through the conductor will be precisely the same in both cases, will it not?

Ans. It will.

Cross-Int. 151. And it is equally obvious, is it not, that the electric tension or pressure or potential of the positively electrified mass will fall to zero much more rapidly when the short, stout wire is used than when the high resistance wire is used?

Ans. It is.

Cross-Int. 152. Is not this just as true when the mass of metal is one pole of a generator as when it is an insulated mass, except as modified by the influx of electricity from the generator?

Ans. If I understand your question correctly, it is.

Cross-Int. 153. In all cases of ring circuits, do not the poles of the generator constantly tend, the one to rise and the other to fall to zero? and is not this tendency very largely modified by the resistance of the conductor joining the two poles external to the generator?

Ans. That is the case.

Cross-Int. 154. You do not think that this conflicts in any way with your answers to Cross-Ints. 144 and 146, do you?

Ans. Not in the least, if I understood the questions correctly.

Cross-Int. 155. Yet it is clear, I suppose, that if the inflow of electric energy or anything else be given, and the outflow be given, the head or pressure follows?

Ans. It is not quite clear to me from your question in exactly what sense the terms "head or pressure" are used. If you ask if the inflow of electric energy at one point of a wire and the outflow from the same point be given, the electro-motive force between the ends of the wire is therefore known, my answer is in the negative. One of the most familiar of electrical laws (the first law of Kirchoff) is, that in any circuit with a steady current the quantity of electricity entering any point in that circuit must be equal to the quantity leaving it.

Cross-Int. 156. Now take the case of the coil. The electricity flowing into the positive pole cannot possibly depend in any way upon the resistance of the conductor leading from that pole, can it; but only upon the magnetic change in the core of that pole?

Ans. Electricity flowing into the positive pole depends primarily upon the magnetic change in the core of the coil. I am not willing, however, to assert that the resistance of the conductor leading from that pole has no effect whatever upon the amount of electricity flowing into it.

Cross-Int. 157. In Fig. 1 of your diagrams the effect of the closed circuit is to cause the potential of the positive pole to fall, and that of the negative pole to rise to zero, is it not?

Ans. The electricity, of course, tends to move from the positive to the negative terminal of the coil through the conducting wire, and if, after the terminals of the coil have become charged, a sufficient time elapses before any other change takes place in them, they will attain and remain at the same or zero potential through the passage of a current of electricity in the conducting wire.

If, however, through the variation of the current in the primary helix of the induction coil the difference of potential between the two terminals of the secondary coil is caused to undergo rapid variations, a series of electrical undulations will be produced in the wire connecting the terminals, which undulations will flow through the wire from the positive to the negative terminal, and, so long as the variations referred to take place, the terminals will not permanently assume the same potential.

Cross-Int. 158. Now take the case of a single motion of armature in Fig. 7, Bell's 1876 patent, as nearly instantaneous as possible, and either towards or from the magnet, but not both. Will there not be a sudden generation of a positive potential at one pole of the coil around the magnet, and an equal negative potential at the other pole of the coil, and will not this produce a discharging current which will instantaneously restore the electric equilibrium of the current so far as that equilibrium was disturbed by that practically instantaneous motion of the armature?

Ans. When the armature moves it produces a rise of potential at one end of the magnet coil and a fall at the other. A slight current of very brief duration, that is, of a duration equal to the duration of the movement of the armature, will ensue. This current will pass through the line wire from one end to the other, and when it has entirely ceased, the voltaic current throughout the circuit will have returned to its original condition.

Cross-Int. 159. Now take the case of the commercial telephone, and suppose the circuit in the primary to be instantaneously made or broken, but not both. Will not that disturb the electric equilibrium of the secondary coil by causing a rise of potential at one of its poles, and a corresponding fall at the other, and will not a current of discharge through the line wire instantaneously restore that equilibrium?

Ans. It will, using the term "instantaneously" to denote a very brief period of time.

Cross-Int. 160. Now take the case of the Dolbear apparatus, and the primary circuit to be made or broken, but not both, as supposed in my last question. Will not the potential of one pole of the coil be raised, and that of the other be lowered; and will not the entire line in electric contact with the positive pole be charged or electrified or brought to the same potential as the then potential of the positive pole, and so of that part of the line connected to the negative pole, if any part of the line be so connected, and will not the current of discharge to restore the electric equilibrium be a reverse current back through the coil?

Ans. The potential of one pole of the coil will be raised and that of the other will be lowered. A sudden electric pulse or current of brief duration will be produced and will flow from the positive terminal through the wire to the plate of the condenser at the farther end of the wire, precisely as the pulse passes through the wire of the ring circuit; but instead of passing completely through a wire to the negative terminal of the coil it flows into that plate of the condenser with which it is connected and charges it positively. At the same time through that part of the line wire connected to the negative pole of the coil a pulse flows toward that pole, and as electricity leaves that plate of the condenser with which this wire is connected the plate becomes negatively charged. When the pulse has ceased the condenser discharges itself through the secondary of the induction coil. You are incorrect in your supposition that the entire line in electric contact with the positive pole is brought to the same potential as the then potential of that pole.

A certain quantity of electricity leaves the positive terminal of the coil and passes through the line wire until it reaches the condenser plate, which it charges. The potential at different parts of the line wire, if this be long, is different and different from the potential of the condenser plate or the terminal of the coil. The quantity of electricity flowing through the line wire and reaching the condenser plate will be greater in proportion as the potential of the terminal of the coil differs from that of the condenser, and in proportion as the resistance of the line wire connecting the condenser with the terminal of the coil is less. If the resistance of the line wire is very great, the changes of potential in the condenser will be small as compared with the changes of potential at the terminal of the coil.

Cross-Int. 161. You seem to me to imagine that the quantity of electricity generated at the positive pole is something like a drop of fluid, and that it leaves the positive pole and travels along through that part of the line wire connected to it, until it reaches the condenser plate, and then spreads itself out on the condenser plate, and although I feel sure that you cannot mean this, yet I feel certain that your answer necessarily implies that the positive pole of the coil, under the conditions supposed in my last question, first becomes electrified and then ceases to be electrified, and that the pulse of electricity leaves it and passes through that part of the line wire in electrical connection with it, and leaving the line wire, gets somehow or other into the condenser plate connected with it. Is this or anything substantially the same as this what you mean by your last answer?

Ans. To a certain extent the interpretation of my answer which you have expressed in the latter part of your question is correct, though I should hardly be willing to accept your statement as it stands. My understanding of the operation to which you refer — to put it briefly — is this: The sudden making of the primary circuit of the induction coil causes the potential of the positive terminal of the secondary coil to be suddenly raised.

This causes an electrical pulse which passes along the line wire until it reaches the condenser. If the positive terminal of the secondary retained its original potential, there would, of course, finally be an equality of potential of all portions of the line wire and condenser, but as the electricity leaves the terminal the potential of the terminal must, of course, fall. Also, if the wire connecting the condenser with the positive terminal of the coil has a very high resistance, the terminal of the coil will partly discharge itself through the secondary helix of the induction coil. These actions will prevent the assumption of an equality of potential by all parts of the circuit. Still more, it must be remembered that the rise of potential of the terminal of the secondary helix is not itself an instantaneous operation, but occupies a time which may be comparable with the time occupied in the passage of the electrical pulse through the line wire.

Cross-Int. 162. You still speak of that pulse as if it was a body and very short, and as if it travelled through the line wire somewhat as a bean goes through a bean blower. You don't mean anything of this kind, do you?

Ans. I must confess that your simile is a somewhat novel one, though it does not clearly express the idea which I had intended to convey. The electrical pulse, as I have figured it, is more nearly anolagous to a short water wave which may be propagated onward with great velocity from one end of a conduit to the other, if, for example, a board immersed vertically in the water is suddenly pushed forward.

Cross-Int. 163. Do you think that you fully understand the operation of the Dolbear apparatus, so far as concerns the secondary coil and the wires attached to it?

Ans. I do.

[*Adjourned.*]

BOSTON, June 16, 1883.

Cross-Int. 164. The terms "electricity" and "electro-motive force" have been very frequently used in this deposition; do you think they are synonymous, practically?

Ans. Neither practically nor theoretically; nor have I ever used them as synonymous.

Cross-Int. 165. Take a case of an insulated mass of metal charged positively, in what units would you express the degree to which it was charged?

Ans. Your question is ambiguous, as the term "degree to which it is charged" may be understood in several different senses, according to which the appropriate unit of measurement would be different. There are several systems of electrical units either one of which we may and do use according as convenience in the special case may dictate. If by the term "degree to which it is charged" you mean what electricians call the quantity of electricity that it contains, then, if we use that system of measurement most common in ordinary practice, we should state this quantity in coulombs. If you mean the difference of potential between it and the earth, this would, in the same system of measurement, be expressed in volts.

Cross-Int. 166. Now suppose two insulated masses of metal, one twice the volume of the other; and suppose first that they are both charged to the same potential, state how the quantity would differ; and second, that they both contain the same quantity, state how the potential would differ.

Ans. It is impossible to answer your question since it does not contain the data which are necessary for the solution, even of the simplest case that might arise.

Cross-Int. 167. What data other than the volume and quantity of electricity do you need to ascertain the potential in the case of a given insulated conductor?

Ans. We must know the shape, size, relative position of the different parts, and, perhaps, the material or the electrical capacity.

Cross-Int. 168. Now please answer Cross-Int. 166, assuming such shape and size and material for the two insulated conductors as you may see fit, except, of course, that the volume of one shall be twice that of the other, and instead of volume I probably should say (although I personally have some doubts about that) superficial area.

Ans. Let us make the simplest supposition, which is, that both of the insulated masses are metal spheres, the surface of one being twice that of the other. If the spheres are charged to the same potential, the quantity of electricity required will be as 1 to 1.4, approximately. The absolute quantity may be measured in coulombs.

If the quantities are the same the relative potentials will be as 1.4 to 1. The potential may be measured in volts.

Cross-Int. 169. In your last answer, might you not properly have used the term "electro-motive force" in place of the term "potential"?

Ans. In stating this result I should not use the term "electromotive force." I do not think that I could use that term without ambiguity unless I stated more than I have stated in my use of the term "potential." Of course there would be an electro-motive force between either of the bodies referred to and the earth, and if either of them were joined to the earth by wire the term "electro-motive force" would in many cases be used. The terms "potential" and "electro-motive force" are not to be regarded as synomymous.

Cross-Int. 170. If you join these two insulated conductors, each being charged with one coulomb of electricity, there would be a transient current commonly called a current of charge, through the wire by which they are joined, would there not? I assume in this question that both are charged positively or both negatively.

Ans. A current will flow from the one at higher potential, that is the smaller, to the one at lower potential, that is the larger, until the outflow of one and into the other, the potential of both bodies and the connecting wire is the same throughout.

Cross-Int. 171. And at the beginning of this current it will be at its maximum strength and it will diminish in strength until it ceases to be a current? And this is the same thing, in substance, as saying that the difference of potential between the two spheres is at the maximum before they are joined by the wire and is reduced to zero by the outflow of electricity from one wire and into the other?

[*Complainants object to the question as immaterial, for the reason that it assumes that the charging body is brought to a certain potential before the connection is made, and that during the operation nothing is done to change that potential except what results from the outflow into and along the conductor, and assumes that this flow is allowed to continue undisturbed long enough for the electricity to come to a state of equilibrium and the flow to come to an end, whereas in the defendants' apparatus when engaged in the transmission of speech the two ends of the conductor start with the same potential, the potential of the sending end is by the necessary operation of the apparatus varied continuously and without interruption, and the rate of variation continually changes; and the interval of time allowed for the restoration of equilibrium between two successive changes is infinitely short because the changes are continuous.*]

Ans. That is substantially the case.

Cross-Int. 172. Now, assume that one of these spheres was charged positively and the other negatively, — but one coulomb, of course, in each sphere, — would not the current then be a current of discharge, and would not both spheres and the connecting wire cease to be electrified or charged?

Ans. Both spheres would cease to be electrified. I do not see, however, that in the case supposed you can draw this distinction between currents of charge and discharge. Taking the case supposed in Cross-Ints. 169, 170 and 171, the current is a current of charge if we consider the changing condition of the body originally at the lowest potential, and a current of discharge if we consider the body originally at the highest potential. In the case which you now suppose we may consider the current a current of charge so far as the negative body is concerned, and a current of discharge so far as the positive body is concerned. Of course these terms are pure conventions.

Cross-Int. 173. When you speak of a quantity of electricity in an insulated sphere of metal, do you imply what might be called "an electric plenum" if you suppose the sphere to be charged positively, and what might be called "an electric vacuum" if you suppose this sphere to be charged negatively?

Ans. That theory of electricity which supposes a body when positively charged to contain more than the normal amount of electricity, and if negatively charged less than the normal amount, is often convenient as an aid to thought. It is to be regarded, however, as a convention. What we know is that there is a difference of electrical condition in the two cases which we can conceive of as arising in some such way.

Cross-Int. 174. You do not believe, do you, that one point of an insulated conductor can have a potential different from that of some other point in the same conductor, and there be no current tending to restore equilibrium of potential?

Ans. Permanently, no; transiently, yes.

Cross-Int. 175. It is a simple matter, is it not, to put the electricity in any insulated conductor into what might be called a state of constraint, so that as long as the conductor is subject to that constraining influence one part of it will be at a different potential from another part of it? Do you mean anything more than this by your last answer?

Ans. Of course if we consider the insulated conductor referred to in your Cross-Int. 174 to be as I considered it in my answer, a wire of the same material and the same temperature throughout, a current will always flow from the points of higher to the points of lower potential, unless there is some force acting to prevent this. I will also add to my answer to the Cross-Int. 174 the statement that if the question does not apply merely to a complete conducting circuit of the same material, and at the same temperature throughout, that there may be a permanent difference of potential without a current.

Cross-Int. 176. In the case of a secondary coil, with both ends grounded or joined by a conductor, electricity is in its normal state in the secondary coil as long as the magnetic energy of the core does not vary; that is to say (in plainer words, perhaps), the coil itself and the circuit joining its terminals is not electrified. Is this right, in your opinion?

Ans. It is; except that the line wire of the circuit may contain a transient current arising from a magnetic variation of the core immediately preceding the moment considered in your question. It of course takes a certain time for the current to cease.

Cross-Int. 177. Now suppose the secondary coil and its circuit unelectrified, a sudden rise of magnetic energy in the core as nearly instantaneous as you can conceive of. Is not the electricity in the core and in the circuit simply put into a state of constraint, one end of the coil becoming positive and the other negative, and these states being almost instantaneously neutralized, owing to the fact that there is a conductor joining the two terminals of the coil?

Ans. One end of the coil becomes positive and the other negative, in accordance with the well-known principles involved in the action of the induction coil. The current flowing through the wire joining the terminals will be very brief, and, supposing the time required to charge the terminals of the coil and the magnitude of the charge to be the same, will depend upon the resistance and capacity of the wire.

Cross-Int. 178. As to the time during which the current flows from the positive to the negative terminal, is it not too plain for dispute that such current flows just so long as the potential of the positive terminal differs from that of the negative terminal, and no longer, regardless of the resistance and capacity of the wire?

Ans. Not necessarily in the case of an impulse of very brief duration.

Cross-Int. 179. Do you mean to intimate that electricity is ponderable or has momentum?

Ans. I do not. The experiments of Maxwell to determine whether electricity did or did not possess momentum resulted in doubt, though no evidences that it does have momentum were found.

Cross-Int. 180. Is there anything whatever that even tends to produce this current over the circuit connecting the terminals of the coil except the difference of potential?

Ans. The current of course results from difference of potential between the terminals of the coil, or between one of the terminals of the coil, and points on the wire, if it be connected to only a single terminal. There are a great many circumstances, however, besides the difference of potential between the terminals, that affect the duration, velocity and strength of the current produced.

Cross-Int. 181. My question related to that case only where the terminals were connected by a wire or where each terminal was connected with the ground, and as we seem to differ somewhat widely, I will restate the entire question.

Isn't it too plain for dispute that the current in the case supposed commences at the same point of time when one terminal is electrified positively and the other negatively, and it lasts just as long as one terminal remains positive and the other negative, and that it ceases at that point of time when the terminals cease to be electrified, and that its commencement, duration and cessation have nothing whatever to do with the resistance or capacity of the conductor joining the two terminals.

[*Same objection as to the Cross-Int.* 171.]

Ans. It is not.

Cross-Int. 182. Your negative answer seems to apply to both portions of my question. For greater certainty, please answer the first part and the second part separately.

Ans. My negative answer applies to both parts of your question.

Cross-Int. 183. Now suppose that the core in the case of the supposed coil with both of its terminals grounded or joined together by a conductor had its magnetic energy increased gradually for a definite length of time, say one minute. Would not the positive terminal become positive as soon as the rising magnetic energy of the core affected the coil, and the negative terminal negative at the same point of time; and would not these terminals remain the one positive and the other negative during all the time that they were affected by the rising magnetic energy of the core; and would not the current begin at that point of time when the terminals became one positive and the other negative and last so long as one remained positive and the other negative, and cease at the point of time when one ceased to be positive and the other negative?

Ans. In the case which you imagine I suppose that the series of electrical changes occurring in the line would substantially occupy the same period as that taken by the terminals of the coil to vary their condition, though the nature of the external conductor would, of course, largely affect the period referred to, so that the period elapsing between the absolute beginning and the absolute ending of the current will not absolutely coincide with the period during which the core is changing its condition.

Cross-Int. 184. Can you refer me to any work on electricity in which is described a secondary coil with its terminals enlarged and opposed, separated by a thin film of air?

Ans. Such apparatus has been used in certain experiments, though it has been much more common to use condensers whose insulating material was paraffined paper than to use air as an insulator.

I have not many references in mind to specific books. In Gordon's researches on the specific inductive capacity of different substances an induction coil was used having its terminals connected by opposed plates separated by an air space. Similar air condensers have been used by various other experimenters. A very brief description of Gordon's apparatus is found in his lectures on static electric induction, and also in his larger work on electricity.

There is also in the English patent of Harrison, No. 4,934, of 1877, an apparatus designed for use as a condenser telephone receiver, which consists of "two or more plates or disks to act as condensers."

The apparatus is shown in Figs. 14 and 15 of the Harrison patent. It consists of two circular plates of metal separated from each other by an intervening air space. When the instrument is to be used as a receiver these plates, in the words of the patent, are "connected with the line wire and the battery or with a secondary coil." The plates are figured as being somewhat convex, but are not described as being necessarily so.

Cross-Int. 185. Is there anything whatever in the Harrison patent about Figs. 14 and 15, or about what you call a condenser telephone receiver, except the following?

According to one method of carrying my invention into effect, I have found that the surface to be connected with the electrododes may consist of two or more plates or discs to act as condensers, as shown at Figs. 14 and 15, Fig. 14 being a face view, and Fig. 15 a side view; these are connected with this line wire and the battery, or with a secondary coil, the current being led through the binding screws A B to the terminal disks C C, which are of metal or other suitable material held in the brass frame or ring that admits of a nice adjustment by the screws D and slide E, at a very small distance apart, according to the degree of potential. I have also found carbon disks or cylinders to be powerful condensers, on account of the immense surface which it exposes in proportion to its size. It is, however, advisable to coat or varnish its back or margin.

Ans. There is not.

CHAS. R. CROSS.

Subscribed and sworn to, before me, this sixteenth day of June, 1883.

WILLIAM A. COPELAND,
Special Examiner.

The examiner here notes that the Dolbear patents, Nos. 239,742, dated April 5, 1881, and 240,578, April 26, 1881, were put in evidence by the defendants as part of their case, as Exhibits Dolbear Patent No. 1 and Dolbear Patent No. 2.

Evidence closed on both sides.

WILLIAM A. COPELAND,
Special Examiner.

LIST OF PUBLICATIONS RELATING TO BOURSEUL AND THE REIS TELEPHONE, PUT IN EVIDENCE BY COMPLAINANTS AND DEFENDANTS, AND PRINTED, pp. 531–623, *infra.*

[The articles numbered 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 23, 24, 25, 26, 30, 31, 35, 37, 38, 41, were put in evidence by defendants, the other articles by complainants.]

PUBLICATIONS ABOUT BOURSEUL.

1. Didskalia, Sept. 28, 1854, No. 232.

2. DU MONCEL, Exposé des Applications de L'Electricité. Vol. 2, p. 225, edition 1854; vol. 3, p. 110, edition 1856. Article by Reis.

3. DU MONCEL in Comptes Rendus, Nov. 26, 1877.

DR. CLEMENS'S PUBLICATION.

4. Deutches Klinik, Nov. 23, 1863, No. 48, pp. 857–9.

PUBLICATIONS BY AND ABOUT REIS.

1861.

5. Frankfurter Conversationsblatt, Nov. 29, 1861.

6. Jahres Bericht des Physikalischen Vereins zu Frankfurt am Main. Fur das Rechnungsjahr, pp. 57–64. 1860, 1861. Article by REIS. (Published in 1862.)

7. Fortschritte der Physik, in Jahre 1861, pp. 171–73.

1862.

8. Zeitschrift des Deutsch-osterreichischen Telegraphen Vereins. Vol. 9, p. 125. Article by LEGAT.

1863.

9. Deutsche Industrie Zeitung, No. 16, p. 184, April 17, 1863.

10. Deutsche Industrie Zeitung, No. 18, p. 208, May 1, 1863.

11. Deutsche Industrie Zeitung, No. 22, p. 249, May 29, 1863.

12. Polytechnisches Notizblatt, Dr. Bottger, No. 6, p. 81.

13. Frankfurter Conversationsblatt, June 30, 1863 (copy of No. 12).

14. Polytechnisches Journal of Dr. Dingler, Vol. 168, p. 185 (reprint of 12).

15. Polytechnisches Centralblatt, 1863, pp. 857–9 (reprint of 12).

16. Jahresbericht des Physikalischen Vereins zu Frankfurt am Main, fur das Rechnungsjahr, 1862–1863, p. 35.

17. Letter Reis to Ladd, July 13, 1863, printed in Journal of the Society of Telegraphic Engineers, 1883, No. 46.

18. The Newcastle Daily Chronicle and Northern Counties Advertiser, August 29, 1863.

19. Report of the thirty-third meeting of the British Association for the Advancement of Science, in August and September, 1863.

20. Albert & Reis prospectus. Frankfort, August, 1863.

21. Albert & Reis circular. " " "

22. Albert & Reis description. " " "

23. Polytechnisches Journal of Dr. Dingler, vol. 169, p. 23 (reprint of Legat article, No. 8).

24. Polytechnisches Journal of Dr. Dingler, vol. 169, p. 399.

25. Fortschritte der Physik, 1863, p. 96.

26. Die Gartenlaube, No. 51, December, 1863.

1864.

27. Cosmos, vol. 24, pp. 349–352, March 22, 1864.

28. Proceedings of the Literary and Philosophical Society, of Manchester, Nov. 10, 1864.

1865.

29. Koenig's Catalogue des Appareils d'Acoustique, p. 5.

30. Pisko's die Neueren Apparate der Akustik, p. 94.

31. Pisko's die Neueren Apparate der Akustik, p. 241 (reprint of 22).

32. Handbuch der Angewandte Elektricitatslehre, Von Karl Kuhn, pp. 1017–1021.

1866.

33. Hassler's Technical Physics. Vienna, vol. 1, p. 648.

34. Albert's Catalogue.

1867.

35. Electricity, by Robert M. Ferguson, London, 1867, p. 257.

1868.

36. Lehrbuch der Physik und Meteorologie, Von JOH. MULLER, 7th ed., vol. 2, pp. 386–389.

1869.

37. The Manufacturer and Builder, May, 1869, vol. 1, p. 129 (Dr. VAN DER WEYDE).

38. The Telegrapher, vol. 5, No. 39 (the same as No. 37).

39. Proceedings Am. Association for the Advancement of Science, August, 1869 (Dr. VAN DER WEYDE).

40. The Boston Daily Advertiser, August 25, 1869 (Dr. VAN DER WEYDE).

41. The Wonders of Electricity, by J. BAILE (*Abbe L'Aborde's tuned-reed circuit-breakers and musical telegraph*).

1873.

42. ALBERT'S Catalogue.

1876.

43. The Scientific American, March 4, 1876 (Dr. VAN DER WEYDE).

44. German report on the exhibition of scientific apparatus in South Kensington Museum, London, 1876, p. 188 (*Reis Telephone*).

1877.

45. Report of the forty-seventh meeting of the British Association for the Advancement of Science, held in August, 1877, published 1878. *On the telephone*, by W. H. PREECE.

46. GANOT'S Elementary Treatise on Physics, eighth edition, translated by E. Atkinson, p. 757.

The Telephone, by AMOS E. DOLBEAR, Boston, Lee & Shepard, 1877, pp. 99–116.

PUBLICATIONS RELATING TO BOURSEUL.

No. 1. DIDASKALIA BOURSEUL ARTICLE.

[Put in evidence by Defendants. No. 34 in answer.]

"DIDASKALIA," Sept. 28, 1854.

The wonders with which electricity has lately astonished us are about, as it seems, to be increased by a new one, that would not only prepare a great revolution in the electric telegraph as practised up to the present, but would increase its usefulness in an incalculable manner.

It is a question of nothing more nor less than an electric transmission of *the spoken word*. The idea originates with a young and educated, though modest young man, Charles Bourseul, who was a soldier of the African army in 1848, where he attracted the attention of the Governor-General by a mathematical course which he delivered to his comrades of the garrison in Algeria, and he is now living in Paris. Bourseul's problem, of the practicability of which he is completely persuaded, belongs, perhaps, to those discoveries which the scientific world afterwards declares very easy, and which they would gladly make us believe could easily have been discovered much earlier if they had chosen to give themselves the trouble.

As is well known, the principle upon which electric telegraphy is based is as follows: An electric current traversing a metallic wire changes a piece of soft iron in the vicinity of which it passes into a magnet. As soon as the current ceases, the magnetic quality also ceases. This magnet, the electro-magnet, can thus alternately attract or let go a movable plate, which by its movements back and forth produces the conventional signals used in telegraphy. Now it is farther known that all tones are brought to the ear only by vibrations of the air, hence are really nothing more than these vibrations of the air, and that the endless variety of tones depends entirely upon the rapidity and amplitude of the sound waves.

Could there now be invented a metallic plate which should be so movable and pliable that it reproduces all the vibrations of tones (like the air), and should this plate be so connected with an electric current that it should alternately make and break the electric current according to the air vibrations by which it was affected, it would thereby be possible also to arrange electrically a second similarly constructed metal plate, so that it repeated simultaneously exactly the same vibrations as the first plate, and it would then be exactly the same as if one had spoken in the immediate vicinity against this second plate, or the ear would be affected precisely as if it received the tones directly through the first metallic wall. The electric telegraph formerly stamped by the Academy as nonsense is now spread throughout all the world as a common phenomenon; if we question in regard to this new idea of a young physicist the principles of physics, they have not only nothing to offer against the possibility of its being carried out, but its success appears inf act to be more probable than did a short time ago that of the electric telegraph itself. If it be practically carried out, the electric telegraph could be operated by every one. There would be need of no farther device and knowledge than a galvanic battery, two vibrating plates and a metal wire; without any other preparation the one must talk against one metallic plate, and the other hold his ear near the other plate, and they could converse with each other as if face to face. The young inventor believes in the success of his efforts, and challenges scientific men to prove that the laws of physics contradict the above-mentioned principles, and thereby make the attempt seem impossible. Meanwhile may the affair enjoy in high degree the attention which it is certainly attracting.

(Didaskalia Magazine for Intelligence, Humor and News, No. 232, 28th of September, 1854.) Translated by A. Stetson.

No. 2. DU MONCEL'S BOURSEUL.

[Put in evidence by the Complainants.]

Du Moncel's Exposé des applications de l' Electricité, vol. 2, p. 225, edition 1854; vol. 3, p. 110, edition 1856, contains the following:—

Electric Transmission of Speech. I have not been willing to give a place in the chapter on electric telegraphy to a fantastic conception of a certain MR. CH BXX, who believes that we may yet be able to transmit speech by electricity, because I might have been asked why by the side of so many remarkable inventions I was willing to class an idea which as presented by its author has not got beyond the condition of a dream. But I have undertaken to mention all of the applications of electricity which have come to my knowledge, and therefore I will here give the information which the author has published up to this time on the subject.

"After the telegraphic marvels, which can reproduce at a distance handwritings, or even more or less complicated drawings, it may appear impossible to penetrate farther into the region of the marvellous, yet we will try to advance a few steps farther. I have, for example, asked myself whether speech itself may not be transmitted by electricity; in a word, if what is spoken in Vienna may not be heard in Paris? The thing is practicable in this way: —

"We know that sounds are made by vibrations, and are made sensible to the ear by the same vibrations, which are reproduced by the intervening medium. But the intensity of the vibrations diminishes very rapidly with the distance; so that even with the aid of speaking-tubes and trumpets, it is impossible to exceed somewhat narrow limits. Suppose that a man speaks near a movable disk, sufficiently flexible to lose none of the vibrations of the voice; that this disk alternately makes and breaks the currents from a battery; you may have at a distance another disk which will simultaneously execute the same vibrations.

"It is true that the intensity of the sounds produced will be variable at the point of departure, at which the disk vibrates by means of the voice, and constant at the point of arrival, where it vibrates by means of electricity; but it has been shown that this does not change the sounds. It is, moreover, evident that the sounds will be reproduced at the same pitch.

"The present state of acoustic science does not permit us to declare *à priori* if this will be precisely the case with syllables uttered by the human voice. The mode in which these syllables are produced has not yet been sufficiently investigated. It is true that we know that some are uttered by the teeth, others by the lips, etc.; but that is all.

"However this may be, observe that the syllables can only reproduce upon the sense of hearing the vibrations of the intervening medium. Reproduce precisely these vibrations, and you will produce precisely these syllables.

"It is, at all events, impossible, in the present condition of science, to prove the impossibility of transmitting sound by electricity. Everything tends to show, on the contrary, that there is such a possibility. When the application of electro-magnetism to the transmission of messages was first discussed, a man of great scientific attainments treated the idea as utopian, and yet there is now direct communication between London and Vienna by means of a simple wire. Men declared it to be impossible, but so it is.

"It need not be said that numerous applications of the highest importance will immediately arise from the transmission of speech by electricity. Any one who is not deaf and dumb may use this mode of transmission, which would require no apparatus except an electric battery, two vibrating disks and a wire. In many cases, as for example in large establishments, orders might be transmitted in this way, although transmission by electricity will not be used while it is necessary to transmit letter to letter, and to make use of telegraphs which require use and apprenticeship. However this may be, it is certain that in a more or less distant future speech will be transmitted by electricity. *I have made some experiments in this direction.* They are delicate, and demand time and patience; but *the approximations obtained* promise a favorable result."

No. 3. DU MONCEL ARTICLE.

[Put in evidence by the Complainants.]

In a paper by Du Moncel and published in *Comptes Rendus*, Nov. 26, 1877, he refers to this notice about Bourseul's plan, and adds:—

However this may be, the fact cannot be concealed that it is Mr. Bell who is the inventor of the telephone, for there is a whole world between a first idea and its definite realization. It is simply because Mr. Bell has made the intensity of the currents which transmit the vibrations of the voice to correspond to the latter in their amplitude and their changes, that the problem has been solved.

DR. CLEMENS' PUBLICATION.

No. 4. CLEMENS' SUGGESTION.

[Put in evidence by Defendants. No. 29 in answer.]

DEUTSCHES KLINIK, No. 48, Nov. 28, 1863, pp. 468–9. *Die Angewandte Heilelektricitat, Von Dr. Th. Clemens, Frankfort-a-M., VI. article. 2d part. Disorders of the Spinal Marrow and their Treatment by Electricity. Foot Note.*

This most wonderful phenomenon of the transmission of sound in the electrified wire I have observed once before, about ten years ago, in the following manner: A strong induction coil was set in motion with one cell of battery, and the current conducted above ground through a copper wire several hundred feet long from my study to a distant garden house. As soon as the wire thus extended was attached at the farther place to a strong coil, one could hear in that farther coil, quite distinctly, the running of the machine and likewise perceive at the second coil any tone which was able in any way to set up strong [bedentenden] vibrations. Shouting into a funnel, blows on a metallic plate, etc., if directed towards the induction coil, were heard distinctly in the farther coil like the tones of an æolian harp. Herein lies more than a wonderful fact in keeping for the future.

PUBLICATIONS BY REIS AND OTHERS RELATING TO THE REIS TELEPHONE.

No. 5. REPORT OF REIS LECTURE.

[Put in evidence by Defendants. No. 31 in answer.]

FRANKFURTER CONVERSATIONSBLATT, Nov. 29th, 1861.

Reproduction des Schalles durch den galvanischen strom (Frankfurt).

"*Reproduction of sound by the galvanic current*" (*Frankfort*).

For this new discovery, which rightly excites the greatest interest, we have to thank Mr. Reis, teacher in Friedrichsdorf. He has succeeded after many experiments in solving, up to a certain point at least, this problem, which up to the present has been considered insolvable.

Of all the new discoveries in natural science there are none of so general advantage and which so enter into our practical life as those in the domain of chemistry and physics; in the latter galvanism in its application to electro-plating and telegraphy has achieved remarkable results. At the moment when telegraphy has attained a place in our social life, there begins, perhaps, for the same a new era in the fact that as we in telegraphy make ourselves understood by means of signs, in this we can make ourselves understood by means of tones at a distance.

Mr. Reis has constructed in a very ingenious manner an apparatus by means of which he has shown some perfectly successful experiments before a large audience in the physical society in this city.

He has made a very happy use of the earlier discovery that the iron core of a wire helix produces tones by the interruptions of the current following each other at very short periods.

His apparatus for receiving the sound is based upon the arrangement of the human ear. It consists in the first place of a funnel-shaped cavity [to represent the cartilage of the ear] to receive the sound, closed at its narrower part by a membrane, upon which is fastened an elastic strip of platinum which is connected with one of the circuit wires, while the former is in electric connection with the other pole of the battery.

As soon, then, as the sound waves set the membrane in vibration, the elastic strip of metal fastened to the same will make the same vibrations, will alternately rise and fall, thereby touching the other elastic strip and so making and breaking the current.

The reproduction of the sound by the galvanic current, for it is only such and not a conduction of the sound, is brought about in the manner specified above. Into a wire helix, included in the circuit, is placed a thin metal rod, — *e. g.*, a knitting needle, — which apparatus, in order to increase the tone, is placed upon an easily vibrating support, a resonant box. By means of the current now made, now broken, the iron rod is also set into vibrations, which are communicated to our ear and there reproduce the sound.

The vibrations of the iron rod correspond with those of the membrane; but as the pitch of the tones is dependent upon the times of vibration of the sounding body, the lower tones escape our notice, while the higher ones are especially noticed.

Up to the present the reproduction of the tones is indeed weak, and words cannot be reproduced. We leave here the question as to whether this hereafter will be successfully accomplished.

Mr. Fritz, instrument maker, has just constructed a new instrument with some improvements, and Prof. Boettger will hereafter make experiments with it in the physical society, to which we shall at times call attention.

No. 6. REIS LECTURE.

[Put in evidence by Defendants. No. 40 in answer.]

JAHRES-BERICHT DES PHYSIKALISCHEN VEREINS ZU FRANKFURT AM MAIN; FUR DAS RECHNUNGS JAHR, 1860–1861.

Yearly Report of the Physical Society at Frankfort-a-M., 1860–61, *pp.* 57–64 (*published in* 1862).

"*On telephony by means of the galvanic current, by Philipp Reis.*"

The extraordinary results in the field of telegraphy have probably often raised the question, If it might not be possible to transmit musical tones themselves [Tonsprache] to a distance? Experiments made in this direction could not, however, produce any result at all satisfactory, because the vibrations of conducting media soon lose their intensity to such an extent that they are no longer appreciable by our senses.

A reproduction of tones [Tonen] at certain distances by means of a galvanic current has probably been thought of, but the practical solution of this problem has certainly seemed the most doubtful to the very persons who, from their knowledge and appliances, were in the best condition to attack it. To a person having only a superficial knowledge of physics the problem presents far less difficulties, simply because the most of them are unperceived. About nine years ago I also (having an extraordinary enthusiasm for what was new, and an insufficient knowledge of physics) had the boldness to attempt the solution, but was soon forced to desist because the very first experiment convinced me of the impossibility of its solution.

Later, after further study and experience, I came to see that my first experiment had been a very rough and by no means conclusive one; I did not, however, follow up the subject seriously, because I did not feel myself equal to the difficulties in the way.

Youthful impressions, however, are strong, and therefore not easily effaced. I could never get rid of the thought of that first experiment and its occasion, notwithstanding all that reason says to the contrary, and thus, half unwillingly, this project of my youth was reviewed in hours of leisure; the difficulties and the means for overcoming them were weighed; but for the present, at least, no experiment was made.

How indeed could a single instrument reproduce the combined effect of all the organs occupied in human speech? This was always the cardinal question; finally I got the notion of putting the question in another way, —

How is *our ear* affected by the totality of vibrations produced by the organs of speech all simultaneously active? Or more generally, —

How are we affected by the vibrations of several simultaneously sounding bodies?

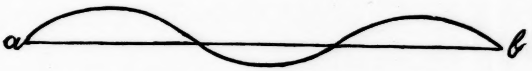
To answer this question, we must, in the first place, understand what must happen in order that we may perceive a single tone.

Without our ear, any tone is nothing else than a recurrent condensation and rarefaction of some body repeated at least seven or eight times in a second. If this occurs in the same medium in which we are, the membrane of the ear is at each condensation forced towards the middle ear, to be moved at the subsequent rarefaction in the opposite direction. These vibrations produce a synchronous raising and falling of the hammer upon the anvil (according to other authorities, an approach or receding of the ear-bone particles), and a similar number of tremors in the fluid of the cochlea, in which the filaments of the auditory nerve are distributed. The greater the condensation of the conducting medium at any giving moment, the greater is the amplitude of vibration of the membrane and hammer, and consequently the more powerful the blow upon the anvil and the vibration of the nerves by means of the fluid.

The office of our organs of hearing is, therefore, to transmit with certainty up to the auditory nerve every condensation and rarefaction occurring in the surrounding medium. But the office of the auditory nerve is to bring to our consciousness the vibrations of matter which have occurred in a given time, both as regards number and amplitude. Here, for the first time, certain combinations receive a name; here, certain vibrations are *tones* or *noises* [*Töne* oder *misstöne*].

What our auditory nerve perceives is, then, simply the effect of a force coming within the range of consciousness, and this force can be represented both as to duration and magnitude graphically by a curve.

Let *a b* represent any given time, and the curve above the line condensation (+), the curve below the line rarefaction (—), then any ordinate raised from the end of any abscissa will represent the degree of condensation, at the time represented by its base, in consequence of which the drum of the ear vibrates.



Our ear can under no circumstances appreciate more than can be represented by these curves, and this indeed is entirely sufficient to give us a clear perception of any tone [ton] or any combination of tones.

If several tones [tonen] are produced at the same time, the conducting medium is subjected to the influence of several simultaneous forces, and the two following laws will hold good: If the forces act in the same direction, the amplitude is proportional to the sum of the forces; if the forces act in opposite directions, the amplitudes are proportional to the difference of the opposing forces.

If, for example, in the case of three tones, we draw the curve of condensation of each separately, then by a summation of the ordinates

at the rarefaction it cannot follow the retreating membrane, of corresponding abscissas, we can determine new ordinates and develop a new curve, which might be called the combination curve. This represents exactly what our ear perceives of the three simultaneous tones. The fact that the musician can distinguish the three tones need not surprise us any more than the fact that any one acquainted with the theory of colors can in green discover blue and yellow; but the combination curves in Plate I. show that this difficulty is a slight one, for in these curves all the relations of the components successively recur. In the case of chords of more than three notes the relations are not so readily seen from the drawing, Plate II., for example. In the case of such chords, however, the skilled musician also finds difficulty in recognizing the separate notes.

Plate III. illustrates discord [Dissonanz]. Why discords impress us unpleasantly I will leave my readers to judge at this time, though I may perhaps return to the subject subsequently in another paper.

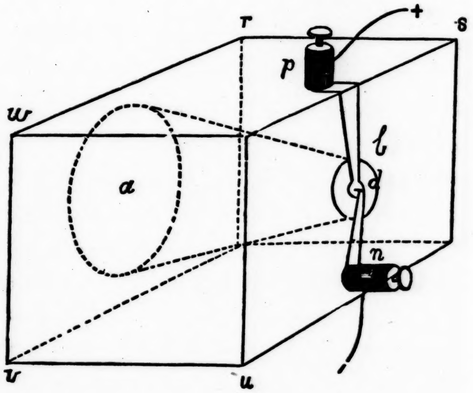
From the preceding it follows: —

First. Every tone [Ton] and every combination of tones, on striking our ear, causes vibrations of the drum of the ear, the succession of which may be represented by a curve.

Second. The succession of these vibrations alone gives us a conception (sensation) of the tone, and every alteration changes the conception (sensation).

As soon, then, as it is possible to produce, anywhere and in any manner, vibrations whose curves shall be the same as those of any given tone or combination of tones, we shall receive the same impression as that tone or combination of tones would have produced on us.

With the above principles as a foundation, I have succeeded in constructing an apparatus with which I am enabled to reproduce the tones of various instruments, and even to a certain extent the human voice. It is very simple, and by means of the figure will be easily understood from the following explanation: —



In the cubical block of wood *r s t u v w x* there is a conical perforation *a*, closed at one end by a membrane *b* (pig's intestine), upon the middle of which there is cemented a conducting strip of platinum; this is connected with the binding screw *p* [auf deren mitte ein stromleitendes Streichen Platin feftgelittet ist. Dieses steht mit der klenme *p* in Verbindung]. From the binding screw *n*, another thin strip of metal [ein dunnes metallstreischen] extends until over the middle of the membrane, and ends here in a platinum wire placed at right angles to its length and surface.

From the binding screw *p*, a conducting wire runs through the battery to the distant station, being connected with a coil of silk-covered copper wire, and this again is connected with a conductor leading back to the binding screw *n*.

The coil at the distant station is about six inches long, is composed of six layers of fine wire, and, as a core in its centre, has a knitting-needle which projects about two inches at both ends. By means of the projecting ends, the coil rests upon two bridges of a resonant case. (All this part can of course be replaced by any other apparatus by means of which the well-known "galvanic tones" can be produced.)

If now tones or combinations of tones are produced in the neighborhood of the block, so that sufficiently powerful waves enter the opening *a*, then these sounds cause the membrane *b* to vibrate. At the first condensation the hammer-like wire *d* is pushed back; at the rarefaction it cannot follow the retreating membrane, and the current traversing the strip remains broken [Strom bleibt so lange unterbrochen bis, *etc.*], until the membrane forced by a new condensation again presses the strip (proceeding from *p*) against *d*. In this way each sound wave causes a breaking and closing [ein Oeffnen und ein Schliessen] of the current [Stromes].

At each closing [Schliessen] of the circuit [kette] the atoms of the iron wire inside the distant spiral are moved away from each other (Pouillet Müller, page 304, Vol. II., fifth edition); on breaking the circuit [beim unterbrechen des Stromes] these atoms seek to regain their position of equilibrium. When this happens, in consequence of the reciprocal actions of elasticity and inertia, a number of vibrations are produced, and they give the longitudinal sound of the rod (see as above). This is the case if the making and breaking of the current [Unterbrechungen und Schliessungen des Stromes] occur with comparative slowness. If they occur more rapidly than the oscillations of the iron core, due to its elasticity, the atoms cannot complete their course. The paths described become shorter in proportion as the interruptions are more frequent, but then are just as numerous as these.

The iron wire no longer gives its longitudinal (normal) tone, but a tone whose pitch corresponds to the number of interruptions [Unterbrechungen] (in a given time); this is the same as saying that *the rod reproduces the tone* [ton] *impressed upon the interrupter* [dem Unterbrechungs apparat]. The intensity also of this tone is proportional to that of the original one, for in proportion as this is more intense the motions of the membrane are greater; the motions of the hammer, also, and finally the time during which the circuit remains opened, is greater, and consequently up to a certain limit, the motions of the atoms in the reproducing wire are greater, we perceiving them as greater vibrations, in just the same way as we would have perceived the original sound wave.

As the length of the conducting wire can undoubtedly be made as great as in direct telegraphy, I have called my instrument "telephone."

Now, in reference to the capabilities of the telephone, it may be stated that I was enabled to render audible to the members of a large assembly (The Physical Society at Frankford-a-M.) melodies which were sung not very loud into the apparatus in another house three hundred feet away, with closed doors.

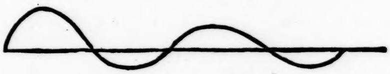
Other experiments showed that the sounding wire was capable of reproducing complete chords of three tones of a piano, upon which the telephone was placed, and that it reproduces equally well the tones of other instruments, accordion, clarinet, horn, organ pipes, etc., provided that the tones are within the compass F—$\bar{\bar{f}}$.

Of course, in all experiments, sufficient precautions were taken to insure that there was no direct conduction of sound. This is very easily done by making a momentary short circuit immediately in front of the coil, by which means its action is temporarily interrupted.

Hitherto it has not been possible to reproduce the tones of human speech [Tonsprache des Menschen] with a distinctness sufficient for every one. The consonants are for the most part reproduced pretty distinctly, but the vowels as yet not in an equal degree. The cause of this I will attempt to explain.

According to the experiments of Willis, Helmholtz and others, vowel tones can be produced artificially, if the vibrations of one body are from time to time augmented by those of another, somewhat as follows: —

An elastic spring is set in vibration by the blow of a tooth on a toothed wheel; the first vibration is the greatest, and each subsequent one is smaller than the preceding.



If, after a few vibrations of this kind (the spring not coming to rest in the mean time), the tooth wheel imparts a new stroke, the following vibration will be again a maximum, and so on.

The pitch of the tone produced in this way depends upon the number of vibrations in a given time, but the character of the tone upon the number of swellings [Anschwellungen] in the same time. Two vowels having the same pitch would differ in about the way represented by the curves (Figs. 1, 2), while the same tone without any vowel character would be represented by the curve (Fig. 3).

Fig. 1.

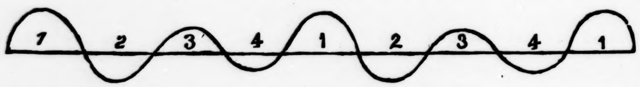


Fig. 2.

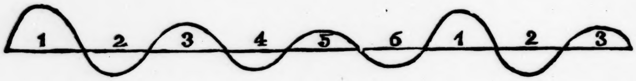
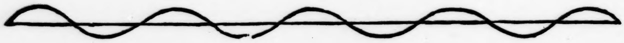


Fig. 3.



Our organs of speech probably produce the vowels in the same manner, through the combined action of the upper and lower vocal cords, or of these latter and the cavity of the mouth.

My apparatus reproduces the number of vibrations, but with an intensity much less than that of the original ones; though, as I have reason to believe, to a certain degree proportional among themselves. But in the case of these generally small vibrations, the difference between large and small vibrations is more difficult to perceive than in the case of the original waves, and the vowel is therefore more or less indistinct.

Whether or not my views as to the curves corresponding to sound combinations are correct could perhaps be decided by means of the new phonautograph of Duhamel ("Vierordt Physiology," page 254).

It may be that for the practical application of the telephone much remains to be done; for physics it has already sufficient interest, from the fact that it opens a new field for research. *Friedrichsdorf, near Frankfort-a-M., December*, 1861.

No. 7. REIS EXHIBITION OF 1861.

[Put in evidence by Defendants. No. 26 in answer.]

FORTSCHRITTE DER PHYSIK, XVII., FOR 1861, pp. 171–3.

PH. REIS. *Telephony by means of the electric current.* (*Annual Report of the Physical Society of Frankfort on the Main*, 1860–1, *pp.* 57–64.)

By the name "Telephone" the author designates the following apparatus of his own construction by means of which and with the help of the galvanic current he is enabled " to reproduce at a distance the tones [Tonen] of different instruments and even to a certain degree the human voice."

A wooden cube is bored through from one of the faces to the opposite one, the cavity taking the shape of a cone; the smaller opening is closed by means of a membrane (hog's intestine, Schweinsdüundarm). On the middle of the membrane and parallel with it is a thin strip of platinum cemented fast at one end whilst the other end is held by a binding post [klemme] *p*. From another binding post *q* extends a similar thin strip of metal as far as over the centre of the membrane, and carries a little platinum wire directed towards the membrane at right angles to the strip and the surface of the membrane. From binding post *p* a conductor leads through a battery to a distant coil, which again is connected by another wire to binding post *q*.

The coil at the distant station is about six inches long, consists of six layers of thin wire and encloses as a core a knitting needle which protrudes about two inches at each end. By these protruding ends the coil is supported on two bridges of a sound board. If now tones or combinations of tones are produced in the vicinity of the large opening of the conical cavity so that sufficiently strong waves enter it, these waves will set the membrane into vibration; by the outward motion of the membrane the platinum strip cemented on it is pressed against the hammer-shaped wire *d* and the galvanic current [strom] is closed [geschlossen]; by the inward motion of the membrane the current is reopened. The alternate magnetizings and demagnetizings of the core of the coil resulting therefrom will bring forth, if the alternation is slow, the longitudinal tone of the core, and if the alternation [aufeinanderfolge] is quicker, a longitudinal vibration of the same, the period of which corresponds to the period of the interruptions of the current [unterbrechungen des stromes] or of the vibrations of the membrane, and consequently to the rate or pitch of the tone which entered the conical cavity. That means according to the author that " The rod [stab] reproduces the tone which was impressed upon the interrupting apparatus [unterbrechungs apparat]." "The strength of this tone is also proportionate to the original tone, for" as the author, though not very accurately, explains, "the stronger this is, the greater the motion of the little hammer, the greater finally the time during which the circuit remains open, and consequently the greater, up to a certain limit, the motion of the atoms in the reproducing rod, which motions affect us as greater vibrations, as the original wave itself would have done." By means of this telephone the author made audible to the members of a large meeting of the Physical Society in Frankfort-a-M. melodies sung not very loud into the apparatus, in a house situated about 300 feet distant, with closed doors. "Other trials showed that the resounding rod is capable of reproducing full chords [dreiklänge] of a piano on which the telephone rests, and that, in short, it reproduces just as well the tones of other instruments, such as the harmonica, clarinet, horn, organ pipe, etc., provided the tones are within a certain range, from F to f^2 or thereabout.

"As a matter of course sufficient care was taken to ascertain whether direct transmission of the sounds had not a share in the result. This was ascertained very simply by establishing for a given time a good shunt circuit directly before the coil, in consequence of which, of course, the activity of the latter ceased for that time.

"It was not possible thus far to reproduce spoken tones [Tonsprache des menschen] with a distinctness satisfactory to all; the consonants are for the most part distinctly reproduced, the vowels not in the same degree." The author attempts to explain this imperfect reproduction of the vowels by saying that the apparatus reproduces the vibrations to a certain extent indeed with proportionate, but also reduced strength, and the ear can no longer satisfactorily discern the relation of the proportionately great vibrations which determine the pitch [Tonhöhe] to the small vibrations on which vocal quality [vocal Farbe] depends.

No. 8. REIS-LEGAT ARTICLE.

[Put in evidence by Defendants. Nos. 19, 27 and part of 28 in answer.]

Journal of the German-Austrian Telegraph Association, V. 9, p. 1, 1862.

Concerning the reproduction of sounds by means of galvanic electricity: by V. Legat, Royal Prussian Telegraph Inspector at Cassel, accompanied by copperplates VIII. and IX.

It might not be uninteresting to make known, in wider circles, the following ideas lately communicated by Mr. Philip Reis to the Society of Physics, and to the meetings of the Free German Institute, at Frankfort on the Main, concerning the reproduction of tones [Tonen] by means of galvanic electricity, and, also, what has been hitherto accomplished towards the realization of this project, in order that the accumulated experiments may serve as a foundation to build upon, and that the capacity of the electric current, which by human ingenuity has already been made serviceable for correspondence, may be developed in this direction also.

In this essay we shall not deal with the electric current as to its capacity for operating telegraphic apparatus of whatever construction for the reproduction of *visible* signs, but of the application of this current to the production of *audible* signals, of *tones* [Tonen].

The air waves, which by acting upon the ear excite in us the sensation of sound by primarily setting the tympanum of the ear into vibratory motion, are, as is well known, transmitted to the interior parts of the ear and to the auditory nerves there located by means of a lever apparatus of wonderful delicacy, the auditory bones (hammer, anvil, stirrup); and the attempt to reproduce tones therefore depends upon this, to actuate an artificial imitation of this lever apparatus by means of the vibrations of a membrane corresponding to the membrane of the ear drum, and thereby to open and close (zum Oeffnen ŭ Schliessen) a galvanic circuit, connected with a distant station by a metallic conductor.

Before describing the apparatus to be used, it would be proper to inquire how our ear apprehends the vibrations of any one particular tone, and the combined vibrations of all simultaneous tones acting upon it, because thereby we may determine the operations which are to be performed by the transmitting and receiving apparatus in the solution of the problem.

Examining first the processes which take place in order that the human ear may apprehend any single tone, we find that each tone is the result of alternate rarefactions and condensations repeated within a fixed time. If this operation occurs in the same medium in which the ear is placed, then at each condensation the membrane is forced toward the cavity of the drum, and toward the opposite side at each rarefaction.

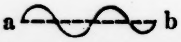
These vibrations cause corresponding movements in the auditory bones, and are thereby transmitted to the auditory nerves.

The greater the degree of condensation of the sound-conducting medium is at a given time, the greater will be the amplitude of vibration of the membrane and auditory bones, and the greater the consequent result; and in the opposite case, so much the weaker. Hence it is evidently the function of the auditory apparatus to impart with faithfulness to the auditory nerves every condensation and rarefaction which occurs in the surrounding medium. On the other hand, the function of transmitting to our consciousness both the number and amplitude of the resulting vibrations occurring within a given time devolves upon the auditory nerves.

It is here, in our consciousness, that a certain complex phenomenon receives a specific name; it is here, in our consciousness, that the transmitted vibrations become tones [Tonen].

Accordingly, that which is apprehended by the auditory nerves is the effect of a force, reaching to our consciousness, and which can be made more easy of comprehension, as to its duration and strength, by graphical delineation.

For example, let the length of the line *a–b* represent a definite period of time, the curves above this line the condensations (+),

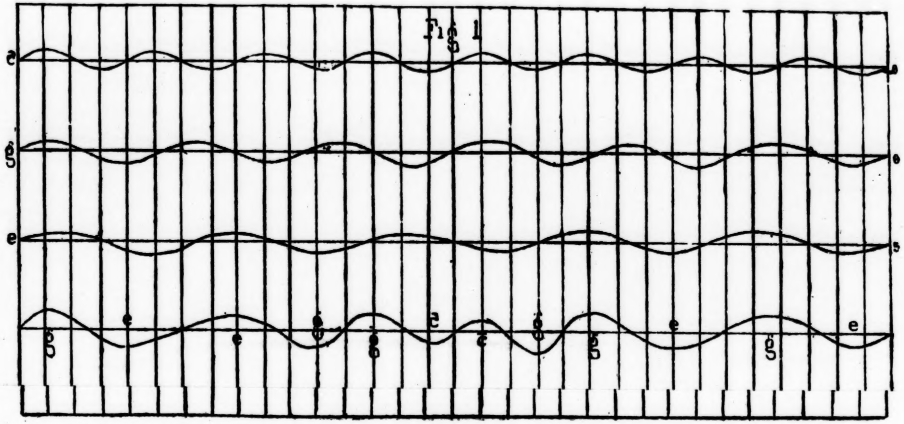


and the curves below this line the rarefactions (—); then every ordinate erected at the end of any abscissa will indicate at the moment of time indicated by this abscissa, the degree of condensation in consequence of which the membrane of the drum vibrates.

Jahrg IX Bl VIII

593 Legat Reproduction von Tönen auf elektro galvanischem Wege

Fig 1



Ernst & Horn Berlin.

The ear is not capable of perceiving more than can be represented in this way, or more than can be represented by similar curves; this is, however, sufficient to convey to our consciousness any single tone [Ton] or any required combinations of tones. For if several tones are generated simultaneously, then the tone-imparting medium is influenced by several forces, acting at the same time, and subject to mechanical laws.

If all the forces act in the same direction, then the amount of motion is in proportion to the sum of all the forces; if on the other hand the forces act in opposing directions, then the amount of motion is in proportion to the difference between the opposing forces.

From these principles it follows that the curves representing the condensations of a number of simultaneously generated tones may be combined in a single curve of condensation, which will indicate with precision what our ear apprehends through the reception of these simultaneously acting tones.

The objection generally made to this proposition, that a musician, or any person, is able to distinguish the simple tones out of which these composite curves are formed or arise, should not be allowed to militate against it; as it is also possible for some who are familiar with the study of colors to distinguish, in green, for example, the mixture of yellow and blue, in their varied shades; and the one phenomenon as well as the other is referable to the fact that each observer is very familiar with the factors of that product which has been conveyed to his consciousness.

By the explanations heretofore given, it is easy to construct the curves representing the condensations of various tones, chords, etc., and a few examples are given by way of illustration: —

Fig. 1, Plate VIII., represents a composite curve formed of three tones, in which all the proportions of the components recur successively.

Fig. 2 represents a similar curve formed of more than three tones; in this case, however, it is no longer possible to represent the proportions so clearly in the drawing, yet an experienced musician will be able to discern them even here, although in practice it might be difficult for him to recognize the separate tones in such a chord.

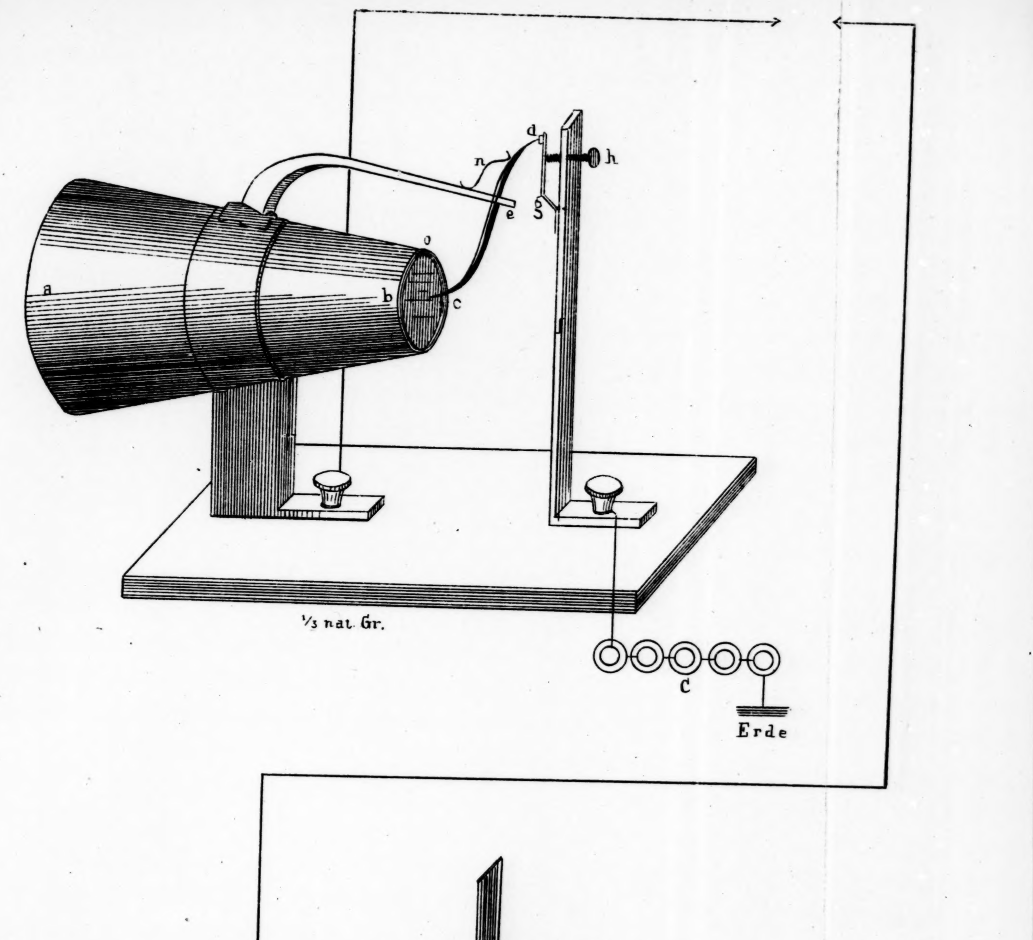
The advantage of representing the operation of tones upon the human ear after this manner is that it gives the clearest view possible of the course of the process; the representation here given also shows why a discord [dissonanz], Fig. 3, must affect the ear disagreeably.

This apparent digression from the subject under consideration was necessary to demonstrate that as soon as we are able, in any place and in any manner, to reproduce vibrations of such curves and intensities as are equivalent to the curves and intensities of the vibrations of any particular tone, or of any particular combination of tones, we shall have the same impressions as were produced upon us by this original tone, or these original combinations of tones.

The apparatus described hereafter offers the possibility of producing these vibrations in every manner desired; and by the use of galvanic electricity it is possible to evoke, at any distance, vibrations like [gleiche] those which have been so produced, and in this way to reproduce at any place the tones which have been generated at another place.

In Plate IX., Fig. 4 A is the tone transmitter [Tonangeber], and B the tone receiver [Tonenppfanger], and these two instruments are set up at different stations. I must observe at the outset that the arrangement of the instruments for sending backwards and forwards is omitted for greater clearness; and likewise, as the whole thing is not presented as a completed fact, but only to call to the notice of a wider circle what has been already ascertained, the possibility of the working of the apparatus at a distance greater than the limited direct working allows at present is left out of consideration, since these points are easily accomplished by mechanical arrangements and since the most important facts of the phenomena treated are not influenced thereby.

Let us now turn to the tone transmitter, Fig. 4 A. This on the one hand is connected by the metallic conductor with the tone receiver, Fig. 4 B, at a neighboring station; on the other hand it is connected by means of the electric battery C with the earth, or with the metallic return conductor. The tone transmitter, Fig. 4 A, consists of a conical tube *a b*, about 15 centimetres in length, hav-


d
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ing a front opening of about 10 centimetres, and a rear opening of about 4 centimetres.

It appears by practical experiments that neither the material of this tube nor any increase in its length influenced the accuracy of the action of the apparatus. An enlargement of the diameter of the tube impairs the working of the apparatus, and it is desirable that the inner surface of the tube be as smooth as possible. The smaller or rear end of the tube is closed by a collodion membrane *o*, and upon the centre of the circular surface of this membrane rests one end *c* of the lever *c d*, the supporting point *e* of which is sustained by a bracket, and is kept in electrical connection with the metallic conductor. The proper lengths of the respective arms *c e* and *e d* of this lever are regulated by the laws of the lever. It is advisable to make the arm *c e* longer than the arm *e d*; in order that the least motion at *c* may operate with greatest effect at *d*. It is also desirable that the lever itself be made as light as possible, that it may follow the movements of the membrane. Any inaccuracy in the operation of the lever *c d* in this respect will produce false tones at the receiving station. When in a state of rest the contact at *d g* is closed, and a delicate spring *n* maintains the lever in this position.

The second part of the apparatus, the standard *f*, consists of a metallic support, connected with one pole of the battery C, the other pole of which is connected to the earth, or to a metallic return wire leading the other station.

Upon the standard *f* is arranged a spring *g*, with a contact point corresponding to the contact point *d* of the lever *c d*; the position of *g* is regulated by the screw *h*.

In order not to impair the operation of the apparatus by the action of the air waves against the rear side of the membrane, it is desirable to place a disk of about fifty centimetres in diameter at right angles to the longitudinal axis of the tube *a b*; this disk may be attached to the tube by a fastening surrounding its outer circumference.

The tone receiver, Fig. 4 B, consists of an electro-magnet *m m*, which rests upon a sounding board *n w*; its coil is connected respectively with the metallic conductor and the earth or the metallic return conductor.

Facing the electro-magnet *m m* is an armature, to which is attached a very long but light and broad lever *i*.

The lever *i* with the armature is suspended from the standard *k* in the manner of a pendulum, its motion being regulated by means of the screw *l* and the spring *q*.

In order to increase the capacity of the apparatus, the tone receiver may be placed at one of the focal points of an elliptical chamber of suitable size, and the listener may place his ear at the other focus of this chamber.

The operation of the apparatus described is as follows: —

When at rest the galvanic circuit [kette] is closed. When the air, which is in the tube *a b* of the apparatus, Fig. 4 A, is alternately condensed and rarefied, by speaking into it (or by singing or introducing the tones of an instrument), a movement of the membrane closing the smaller opening of the tube is produced, corresponding to such condensation or rarefaction. The lever *c d* follows the movements of the membrane, and opens and closes [öffnet und schliesst] the galvanic circuit [kette] at *d g*, so that at each condensation of the air in the tube the circuit is opened, and at each rarefaction the circuit is closed [ein Oeffnen und ein Schliessen erfolgt].

In consequence of this operation, the electro-magnet of the apparatus, Fig. 4 B, in accordance with the condensations and rarefactions of the column of air in the tube *a b*, Fig. 4 B, is correspondingly demagnetized and magnetized [demagnetisirt und magnetisirt] and the armature of the magnet is set into vibrations like those of the membrane in the transmitting apparatus. But the beam (Balken) *i* attached to the armature communicates these corresponding vibrations of the armature to the air surrounding the apparatus Fig. 4 B, which finally transmits the vibrations so produced to the ear of the listener.

We have not here to consider the question of the transmission [Fortpflanzũng] of tones by means of the galvanic current, but only of the conveyance [Uebertragũng] of generated sounds to another place, and in this way that at the latter place a similar cause is produced, and a similar effect obtained. It must not be ignored, however, that while the apparatus described reproduces the exact number of the original vibrations, but not of the same strength (die gleiche stärl [illegible] r reproducirten schuingüngen noch nicht erreicht nurde); and that the achievement of this result is reserved for an improvement of the apparatus.

In consequence of the imperfection of the apparatus at this time, the minor differences of the original vibrations are distinguishable with more difficulty,— that is, the vowel sounds appear more or less indistinct, — inasmuch as each tone depends not merely upon the number of the vibrations of the medium, but also upon its condensation and rarefaction.

This also explains why chords and melodies were transmitted with marvellous accuracy in the practical experiments hitherto made, while single words in reading, speaking, etc., were less distinctly recognizable, although even in these the inflections of the voice, as in interrogation, exclamation, surprise, calling, etc., were clearly reproduced.

There is no doubt that the subject we have been considering, before it becomes practically valuable for use, will require considerable improvement; it will especially be necessary to perfect the mechanism of the apparatus to be employed; but I am convinced, by repeated practical experiments, that it is of the greatest theoretic interest to pursue these investigations, and also that a development of practical value will not elude our intelligent century.

Nos. 9, 10, 11. INDUSTRIAL GAZETTE.

[Put in evidence by Defendants. No. 30 in answer.]

"*Deutsche Industrie Zeitung*," 1863, *Chemnitz*.

No 9, April 17, 1863, No. 16, page 184: —

"*Industrial Queries for Exciting Interest and Eliciting Responses.*

"Of late there has been talk in newspapers about producing definite tones at a distance, similarly to telegraphic despatches, such for instance as conducting the acoustic effects of an instrument far beyond the reach of the audibility of its sound. Do these communications rest upon actual facts?"

No. 10, May 1st, 1863, No. 18, page 208: —

"Answers. Answer to question in No. 16, page 184. Transmission of Tones by Electricity. According to the 'Bottger's Notizblatt,' 1863, No. 6, successful experiments in 'telephony' were made in October, 1861, at Frankfort-a-M. by Prof. Ph. Reis, so that it seems not impossible to carry on conversations at miles distance, and even to convey the voice itself with its peculiar undulations, and also the tones of a musical instrument. Heretofore the voice could be reproduced from one house to another only for a distance of 300 feet by means of a peculiar and ingenious apparatus. The arrangement of the same was essentially as follows: The waves of sound were taken up by an elastic surface and transmitted to a light commutator introduced into the circuit of a galvanic battery [einer federnden cummutator eingeschaltet in den Leitungsdraht]. At the other end of the line was introduced a coil of copper wire, inside of which was an iron wire resting upon a sounding board, that was thrown into sonorous vibrations by the changes of current depending upon the waves of sound."

No. 11, May 29, 1863, No. 22, page 249.

"*The reproduction of tones by electro-galvanic means (with a drawing, which is the same as the drawing of the apparatus in the Legat article, No. 8, pp. 539–45 supra).*

"Although this subject has already been discussed by us (No. 18, page 208), on account of the great interest it offers, we shall return to it more in detail. We enclose a drawing of an apparatus used by Mr. Ph. Reis in Frankfort-a-M., taken from the Zeitschrift des Deutch-Oestereichschen Telegraphen Vereins, 1862, folios 6, 7 and 8. We take the liberty of following the lead of the above-mentioned source in entering into a short discussion of the nature of tones.

"The undulations of the air that excite in us, by operating upon the ear, the sensation of sound, by setting the drum of the ear into vibration, are transmitted, as is well known, by a series of levers of admirable delicacy, that is, by the small bones of the ear (hammer, anvil and stirrup) to the inner portion of the ear and to the nerves that lie at that point. The attempt to reproduce tones depends upon the following: to set in motion an artificial imitation of this series of levers by the vibration of a membrane which takes the place of the drum, and to make use of them to open and close a galvanic circuit which is connected by a metallic conductor with a remote station.

"If we take into consideration the phenomena that take place when we perceive a sound by the sense of hearing, we find that every tone is the result of rarefactions and condensations of the air repeated several times in a certain period. At every condensation the membrane of the drum is pressed inwards, and at every rarefaction outwards. These vibrations produce a simultaneous motion of the small bones of the ear and a consequent transmission to the nerves of the ear. The greater the compression of the sound-conducting medium at any particular moment, the greater is also the amplitude of vibration of the membrane and small bones of the ear, and *vice versa*. The object, therefore, of the organs of hearing is to transmit with certainty the rarefactions and condensations of the sound-conducting medium to the nerves of hearing. On the other hand, it remains their object to bring to our perception the vibrations occurring in a given time with reference to number as well as to amplitude. It is only in our perceptions that a given combination receives a definite name, that vibrations become sounds.

"Anything other than the effect of such single vibrations the organs of hearing are unable to take up, and these organs themselves are competent to perceive single tones as well as combinations of tones, for if several tones are produced at the same time the sound-conducting medium is under the influence of several simultaneous forces which according to the laws of mechanics can be replaced by a force which produces the same effect as all the single ones together. If all the forces operate in the same direction the magnitude of the motion is proportional to the sum; if they operate in opposite directions the magnitude of the motion is proportional to the difference of the opposite forces. In that way several simultaneous tones operate upon our hearing simply by a definite alternation of rarefactions and condensations of the sound-conducting medium, as in the case of single tones. The tone itself depends apparently only upon the number of vibrations and the power upon the amplitude of the vibrations (perhaps also the strength).

"Now, as regards the apparatus, the upper figure is the transmitter and the lower one the receiver or reproducer.

"The transmitter consists of a metallic conical pipe *a b*, about 15 centimetres in length, 10 in diameter at *a* and 4 in diameter at *b*. At *b* the opening is closed by a membrane *o* of collodion stretched tight. Upon the centre of the same rests the end *c* of lever *c d*, whose fulcrum is placed at *e* on a support. The lever is to be made as light as possible, and its arm *c* longer than its arm *d*, so that the smallest motion at *c* will operate at *d* with the greatest amount of force. In the condition of rest the contact *d g* is closed and a weak spring *n* holds the lever fast in this position of rest. Besides, there is attached to the apparatus a metallic standard *f*, connected with one pole of the battery, while the other pole is led to the ground through *e*. On the standard *f* is secured the spring *j* opposite the contact point *d* of lever *c d* at *d*, the position of which (spring) can be regulated by a screw *h*.

"The receiver consists of an electro-magnet *m m* resting upon a sounding board R, and whose coils are in connection with a metallic conductor and with the earth at E. Opposite the electro-magnet is an armature connected with a lever, as long as possible, but light and broad. This lever is fastened to the support *k* after the manner of a pendulum, and its motions are regulated by a screw *b* and spring *g*.

"To increase the efficiency of the apparatus the receiver and reproducer can be set up in one focus of an elliptical concavity of proper size, while the listening ear of the hearer is placed in the other focus.

"The operation of the apparatus is now as follows: The tones of the voice or of an instrument are conducted into the conical pipe *a b*. By reason of their vibration the membrane is set into similar vibration and in this way operates the opening and closing of the electric conductor. In consequence of this the magnet in the receiver will be magnetized and demagnetized corresponding to the vibration of the tones, and the armature of the lever *i* is set in vibrations corresponding to those of membrane *o*. The wide surface of lever *i* transmits these vibrations to the air, and by this means they reach the ear of the hearer. In this transmission of tones, the only question is one of transmission of vibrations, a problem that magneto-electric telegraphy is certainly sufficiently far advanced to deal with.

"A friendly communication was sent us some time ago by Mr. J. F. Quilling of Frankfort-a-M., according to which the capacity of the apparatus to transmit tones to a considerable distance clearly and with their characteristic timbre [Klangfarbe] is fully established. Mr. Q. writes us that by means of the telegraphic conductor with which the apparatus of Mr. Ph. Reis was connected, two remote parts of the city were united, and although it was not possible with the present construction of the apparatus to transmit spoken words [gesprochenen Wörte], they succeeded so well with the tones that were sung that not only were the melodies of songs reproduced distinctly and perfectly at a tolerably remote station, but known voices could be recognized. All present capable of judging, Mr. Q. adds, who availed themselves of the opportunity of witnessing the experiment, agreed that the possibility is before us of making one's self understood verbally at any distance in the way shown by Mr. Reis."

No. 12. BÖTTGER'S ARTICLE.

[Put in evidence by Defendants. Nos. 31, 32, 33 and part of 28 in answer.]

Böttger's Polytechnisches Notizblatt, 1863, *No.* 61. *On the Transmission of Tones at any desired Distance, by Means of Electricity.* (*Telephony.*)

Two decades ago the problem of giving signs, by means of electricity, from distances had not yet been entirely solved. Since then telegraphy has reached such a perfection and telegraph wires have so greatly spread that even the keenest desires have not much left to ask for.

Now there appears a first earnest trial to reproduce tones at any desired distance, by means of electricity.

This first trial, which has been crowned with success, has been repeated in the lecture room of the Physical Society of Frankfort-on-the-Main, before numerous assembled members, on the 26th of October, 1861, by Mr. Ph. Reis, teacher of natural sciences at Friedrichsdorf, near Frankfort. Into one part of his apparatus, located in a building about three hundred feet distant, and having all the doors and windows closed, melodies were sung, but not very loudly. The same could be heard by the members in the lecture room, through the second part of the apparatus.

These wonderful results were attained with the following very simple apparatus: A small, light box, a kind of hollow wooden cube, has a larger opening in the front, and a smaller one on the opposite side. The latter is covered with a very fine membrane (sausage skin), and the same is tightly stretched; a small, flexible piece or strip of platina, fastened to the wood of the box, touches the membrane at its centre, and a second strip of platina is fastened by one end to the wood at a different place, and has at its other end a fine horizontal point touching the other strip of platina, where it lies on the membrane.

As is known, tones are produced by the rapid succession of condensations and rarefactions of the air. If the vibrations of the air, called waves, strike the thin membrane, they push the same against the strip of platina that touches it, and then allow it to immediately vibrate back into the hollow cube (called the artificial ear), and so cause the membrane to assume forms alternately bent towards the cube and from the same. The strip of platina lying against the membrane is thus set into a swinging motion, so that it is alternately pressed on to the platinum point of the second strip and then leaves the same.

If one of the strips is connected by a wire to one of the poles of a voltaic battery, and the electricity is conducted to any desired distance by a wire connected to the other pole and is then carried through a helix six inches in length, wound with six layers of thin silk-covered copper wire, and from there is carried back to the second strip of platina on the wooden cube by means of an insulated wire, then, at every vibration of the membrane, an interruption of the current of electricity [Unterbrechungen der Stromung der Electricitat] will be caused, as the point on the one strip of platina no longer touches the other strip. Through the hollow of the spiral a thin iron wire (a thick knitting needle) about ten inches in length is passed, so that it projects out of each end of the spiral about two inches, and these projecting ends each rest on a bridge of a sounding board.

It is known that if an electric current is passed through a helix that surrounds an iron wire, at every interruption a tone, produced by the vibrations of the iron wire, is audible. If the makings and breakings of the current [Unterbrechungen des Stromes] follow each other rather slowly, the different positions (in regard to the length of the bar) which the molecules will be caused to assume by the electricity will produce a tone, its so-called proper longitudinal tone, which depends on the length and thickness of the bar or wire.

If the interruptions and reconnections of the current [Unterbrechungen des electrischen Stromes] in the spiral take place faster than the vibrations of the smallest parts of the wire, which in turn depends upon the elasticity of the wire, they cannot complete their course, receive new shocks, the vibrations get to be smaller but more rapid, and as numerous as the interruptions follow each other. The piece of wire no longer gives its longitudinal tone, but a tone which, according to the number of interruptions in a certain time, is higher if they are more frequent and lower if they are less frequent. It is known that the pitch of a tone depends on the number of air waves that follow each other in one second. We have seen that the number of interruptions of the electric current [Unterbrechungen des electrishen Stromes] by the membrane and the strips of platina is dependent upon this.

Consequently the iron wire must give a tone of the same pitch as the sound which was received by the membrane. As electricity is hardly impaired when conducted a great distance, if the proper apparatus is used, it is evident that a tone acting on a membrane in one place can be made audible at any desired distance by the iron wire.

That the tone is made audible only by electric vibrations and not by direct transmission of the air waves through the wires can be most strikingly proved by noticing the fact that no tone is heard at the spiral if a good short circuit be established; *i. e.*, if, for instance, a small strip of metal is laid across the two wires, directly in front of the spiral. The reproduced tones are weaker than the originals, but the number of vibrations is the same. It is easy to reproduce the tones in the proper pitch. As the vibrations are smaller, which is the cause of the weakness of the tone, it is much more difficult, however, for our ear to estimate the difference in the size of the vibrations.

The character of a tone depends upon the number of swellings it has; *i. e.*, with tones of the same depth, consequently of the same number of waves per second, such as having the fourth, sixth, eighth, tenth or sixteenth wave stronger than the rest.

The physicists have shown that if a spring is vibrated by the teeth of a cog wheel, the first vibration is the greatest, and every following one is smaller. If, however, before the spring comes to rest, another tooth strikes it, then the next vibration will be equal to the first strongest one, but the vibrations of the spring will not be any more numerous than before. Vowel tones can be artificially produced in this way.

Although we may be far from being able to converse with a friend a hundred miles away and recognize his voice, as though he was sitting alongside of us, the impossibility of attaining this result can no more be claimed.

The probability that this result will be attained is almost as great as, by the wonderful experiments of Niepce, the reproduction of natural colors by photography.

No. 13. FRANKFUR TER CONVERSATIONSBLATT, FOR JUNE 30, 1863.

[Put in evidence by Defendants. No. 31 in answer.]

(This is a reprint of Bōttger's article, No. 12, *supra.*)

No. 14. POLYTECHNISCHES JOURNAL OF DR. DINGLER, Vol. 168, p. 185.

[Put in evidence by Defendants. No. 28 in answer.]

(This is a reprint of Bōttger's article, No. 12, *supra.*)

No. 15. POLYTECHNISCHES CENTRALBLATT, 1863, pp. 857-9.

[Put in evidence by Defendants. No. 32 in answer.]

(This is a reprint of Bōttger's article, No. 12, *supra.*)

No. 16. JAHRESBERICHT DES PHYSICALISCHEN VEREINS ZU FRANKFURT AM MAIN FÜR DAS RECHNUNGSJAHR, 1862-1863, P. 35.

[Put in evidence by the Complainants.]

The following papers were also presented in the Saturday session, namely, on the 4th of July, 1863, by Ph. Reis of Friedrichsdorf; "transmission of sounds to any requisite distance by means of electricity," the paper being accompanied with an exhibition of an improved telephone and the performance of experiments with it. [The paper was not printed.]

No. 17. REIS'S LETTER TO LADD.

[Put in evidence by Complainants.]

Journal of the Society of Telegraph Engineers and of Electricians for March, 1883, *No.* 46.

REIS'S TELEPHONE.

The following is a copy of an autograph description of Reis's telephone which has been presented to the library by Mr. Wm. Ladd, Member: —

(Copy)

INSTITUT GARNIER,
FRIEDRICHSDORF.

Dear Sir:

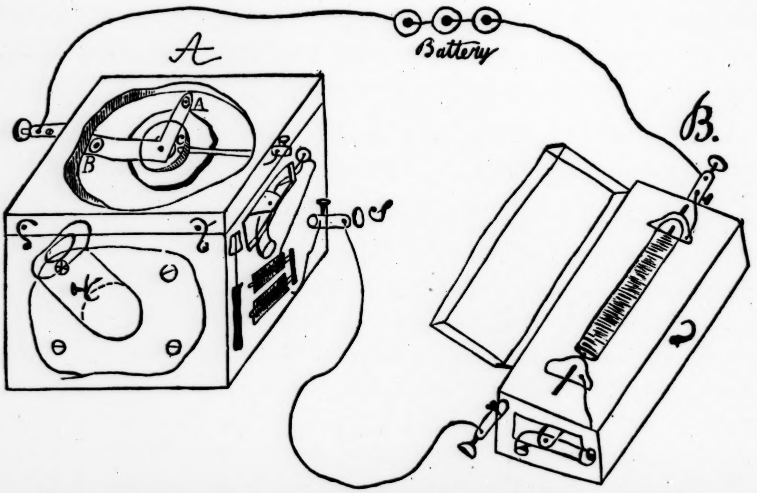
I am very sorry not to have been in Francfort when you were there at Mr. Albert's, by whom I have been informed that you have purchased one of my newly-invented instruments (telephons), though I will do all in my power to give you the most ample explanations on the subject. I am sure that personal communication would have been preferable, specially as I was told that you will show the apparatus at your next scientifical meeting, and thus introduce the apparatus in your country.

Tunes and sounds of any kind are only brought to our conception by the condensations and rarefactions of air or any other medium in which we may find ourselves. By every condensation the tympanum of our ear is pressed inwards, by every rarefaction it is pressed outward, and thus the tympanum performs oscillations like a pendulum.

The smaller or greater number of the oscillations made in a second gives us, by help of the small bones in our ear and the auditory nerve, the idea of a higher or lower tune.

It was no hard labor, either to imagine that any other membrane beside that of our ear could be brought to make similar oscillations, if spanned in a proper manner and if taken in good proportions, or to make use of these oscillations for the interruption of a galvanic current. However, these were the principles which guided me in my invention; they were sufficient to induce me to try the reproduction of tunes at any distance. It would be long to relate all the fruitless attempts I made until I found out the proportions of the instrument and the necessary tension of the membrane. The apparatus you have bought is now what may be found most simple, and works without failing when arranged carefully in the following manner: —

The apparatus consists of two separated parts, one for the singing station, A, and the other for the hearing station, B.



Reis's Telephonic Apparatus.—Facsimile of Drawing sent by Reis to Mr. Ladd.

The apparatus A is a square box of wood, the cover of which shows the membrane, *c*, on the outside, under glass. In the middle of the latter is fixed a small platina plate to which a flattened copper wire is soldered, on purpose to conduct the galvanic current. Within the circle you will further remark two screws; one of them is terminated by a little pit in which you put a little drop of quicksilver, the other is pointed. The angle, which you will find lying on the membrane, is to be placed according to the letters, with the little hole *a* on the point *a*, the little platina foot *b* into the quicksilver screw, the other platina foot will then come on the platina plate in the middle of the membrane.

The galvanic current coming from the battery (which I compose generally of three or four good elements) is introduced at the conducting screw near *b*, wherefrom it proceeds to the quicksilver, the movable angle, the platina plate and the complementary telegraph to the conducting screw *s*. From here it goes through the conductor to the other station B, and from there returns to the battery.

The apparatus B, a sonorous box on the cover of which is fixed the wire spiral with the steel axis, which will be magnetic when the current goes through the spiral. A second little box is fixed on the first one, and laid down on the steel axis to increase the intensity of the reproduced sounds. On the small side of the lower box you will find the corresponding part of the complementary telegraph.

If a person sing at the station A, in the tube *x*, the vibrations of air will pass into the box and move the membrane above, thereby the platina foot *c* of the movable angle will be lifted up, and thus will open the stream at every condensation of air in the box. The stream will be re-established at every rarefaction. In this manner the steel axis at station B will be magnetic once for every full vibration, and, as magnetism never enters nor leaves a metal without disturbing the equilibrium of the atoms, the steel axis at station B must repeat the vibrations at station A, and then reproduce the sounds which caused them. *Any* sound will be reproduced if strong enough to set the membrane in motion.

The little telegraph which you find on the side of the apparatus is very useful and agreeable for to give signals between both of the correspondents. At every opening of the stream, and next following shutting, the station A will hear a little clap, produced by the attraction of the steel spring. Another little clap will be heard at station B in the wire spiral. By multiplying the claps and producing them in different measures, you will be able as well as I am to get understood by your correspondent.

I am to end, Sir, and I hope that what I said will be sufficient to have a first try; afterwards you will get on quite alone.

I am, Sir,

Your most obedient servant,

PH. REIS.

FRIEDRICHSDORF, 13-7-63.

To Mr. William Ladd.

No. 18. BRITISH ASSOCIATION ON REIS.

[Put in evidence by Complainants.]

The Newcastle Daily Chronicle and Northern Counties Advertiser.

Saturday, August 29, 1863.

SECTIONAL MEETINGS.

(Yesterday.)

A. — Mathematical and Physical Science.

President: — W. J. Macquorn Rankine, C. E., F. R. S.

Vice-Presidents:—General Sabine; Professor Sylvester; and W. Spottiswoode, F. R. S.

Secretaries: — Professor Stevelly, LL. D.; Rev. C. T. Whitley, M. A.; Professor H. I. S. Smith, M. A., F. R. S.; Professor Fuller; and the Rev. W. Ferrers.

Mr. Ladd then exhibited an acoustic telegraph for the transmission of musical notes and sounds between distant points, this ingenious contrivance being the invention of a schoolmaster at Frankfort, whom Mr. Ladd had met with in his travels. By means of this telegraph sounds were transmitted from one end of the table to the other, the sounds (which are produced by the principle of vibration) being heard fainter than they were uttered. Mr. Ladd, however, expressed his opinion that distance would not militate against the power of the telegraph to transmit sound. At the same time, he admitted it was of no practical use, but was merely a scientific toy.

Professor Stevelly said that Mr. Ladd might be able to talk through his telegraph.

Mr. Jenkyn: He may whistle a tune through it, at any rate.

No. 19. BRITISH ASSOCIATION REPORT ON REIS.

[Put in evidence by Complainants.]

Report of the Thirty-third Meeting of the British Association for the Advancement of Science in August and September, 1863; *published* 1864.

On An Acoustic Telegraph, by W. Ladd.

This instrument consists essentially of two distinct pieces of apparatus; that for transmitting the signal has a small mouthpiece. On the right-hand side there is a finger key forming part of the circuit, and an electro-magnet, with a vibrating armature and binding screw to connect with one of the line wires. Within a case under a glass cover is an elastic membrane, in the centre of which is fixed a platinum plate in connection with the finger key. A like piece of angular metal resting on three pins is so placed that the pin at the angle rests on the plate in the centre of the membrane, the other two resting in cups on its edge so as to allow a free motion on the points. In the body of the receiver box is suspended a soft iron core surrounded by a coil of silk-covered wire, one end of which is in connection with a finger key and the other with the binding screw. The method of producing sound in the receiving instrument depends upon the fact that at the moment of magnetizing or demagnetizing a piece of iron there is an alteration in the arrangement of the particles which gives rise to a slight ticking noise. Having connected the transmitter by means of an insulated wire with the receiver, and the binding screws having been brought in connection with a battery of three or four elements, if the finger key on the transmitter be pressed the person at the receiving station hears the ticking noise. To convey a musical note or sound the operator places his mouth to the tube in front of the instrument and sings a note, when immediately the membrane begins vibrating in accordance with the note sounded, and at each vibration breaks contact between the pin and plate in its centre. This forming part of the circuit causes the iron core in the receiving instrument to be magnetized and demagnetized a number of times equal to the number of vibrations of the membrane, and so conveys to the receiver an impression of a musical sound. The finger keys and small magnet at the sides of the instruments are for the purpose of varying the methods of communication by the combination of single sounds, and can also be used with the other parts for the purpose of regulating the lengths of the notes and dividing them into varying portions, so as to form a sound alphabet somewhat similar to the signals written by Morse's telegraph.

No. 20. PROSPECTUS OF MR. ALBERT.

[Put in evidence by Defendants.]

J. Wilh. Albert,
Mechanician,
Frankfort on the Main,

Frankfort-a-M., August, 1863.

Sir:

I take the liberty of sending you the accompanying prospectus, begging you to give it your kind attention; it relates to the very interesting apparatus of Mr. Reis, for the production of tones with the aid of galvanism:

THE TELEPHONE.

This apparatus, which can be had through me, is at all times exhibited for inspection in my warehouse, and besides I am quite willing to give every information regarding it. My warehouse of physical, optical and chemical instruments and apparatus is now: Neue Mainzerstrasse-No. 34 AM. Taunusthor, only three minutes' walk from the several railroad stations, and therefore may be visited by any one, however short his stay in Frankfort may be.

Awaiting your kind order, I am,

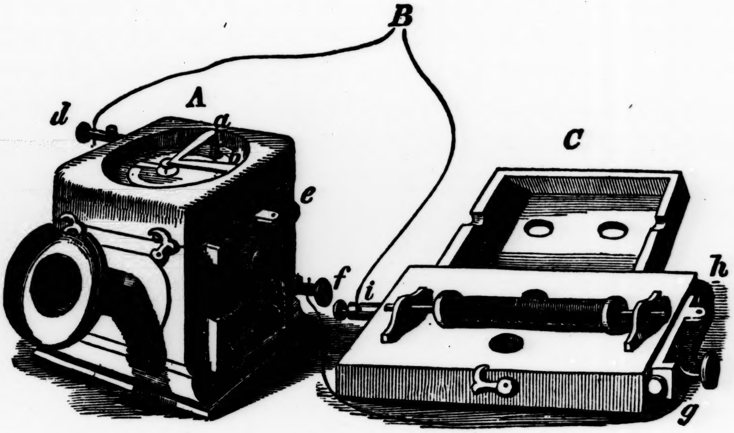
Respectfully yours,

J. WILH. ALBERT.

No. 21. CIRCULAR OF REIS.

[Put in evidence by Complainants.]

(*This is on the same sheet of paper as the foregoing.*)



Sir:

Having succeeded two years ago in demonstrating the possibility of reproducing tones with the aid of the galvanic current and in manufacturing an apparatus for that purpose, the subject has been so highly appreciated by the most renowned men of science, and I have received so many encouragements, that I have striven since that time to improve my originally very imperfect apparatus, in order to give to others also the facility of experimenting.

I am now able to offer an apparatus which satisfies my expectations, and with which every physicist will succeed in repeating these interesting experiments regarding the reproduction of tone (Ton = reproduction) at distant stations.

I believe that it is the wish of many that these instruments should come into the possession of laboratories; as, however, their manufacture demands a complete knowledge of the leading principles and a great experience in this matter, I have resolved to make the most important parts myself, and to intrust to the mechanician only the secondary parts and the external outfit. Mr. J. Wilh. Albert, mechanician at Frankfort on the Main, is commissioned to sell them.

I have enabled him to offer them at the prices of 21 and 14 florins (12 and 8 Prussian thalers) in two qualities, which differ only in the external outfit. The instruments can also be had directly from me at the same price by cash payment. Every apparatus is examined by me before being shipped, and has attached my name, the serial number and the date of construction.

FRIEDRICHSDORF b. HOMBURG, v. d. HÖHE,
August, 1863.

PHIL. REIS,
Teacher at L. F. Garnier's Boys' Institute.

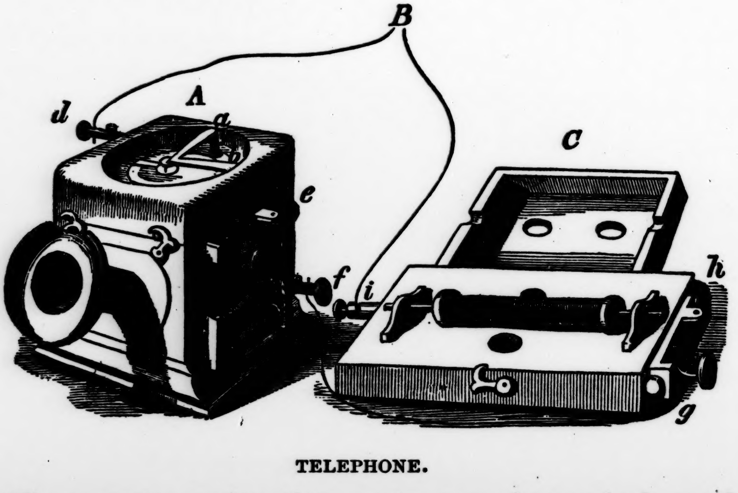
(In manuscript on the foregoing is the following:—)

Descriptions of the above are to be found in Müller-Pouillet's Lehrbuch der Physik, Braunschweig, Vieweg & Son; Pisko, die Neueren Apparate der Akustik, Wein, Gerold's Son, 1865.

No. 22. REIS'S DESCRIPTIVE CIRCULAR.

[Put in evidence by Complainants.]

(*This and the foregoing are on two similar printed sheets.*)



TELEPHONE.

The apparatus consists of two parts, as may be seen in the woodcuts above, the telephone proper A, and the reproducing apparatus

C. These two parts are to be placed at such a distance from each other that singing or the sound of a musical instrument can be heard in no other manner except through the apparatus from one station to another.

Both parts are connected with each other and with the battery B, the same as in an ordinary telegraph. The battery must be sufficient to produce at station A the attraction of the armature of the electro-magnet placed at one side (three or four six-inch Bunsen cells are sufficient for several hundred feet of distance).

The galvanic current then goes from B to the binding post *d*, from there through the copper strip, to the platina disk in the centre of the membrane, then through the foot *c* of the angle towards the binding post B, *in the small hollow of which a drop of quicksilver is inserted*. From here the current goes through the small telegraph apparatus *e f*, then to the key of the station C and through the coil surrounding *i* back to B.

If now sufficiently strong tones are produced before the mouthpieces, their vibrations will put in motion the membrane and the angular little hammer [winkelförmige Hämmerchen] which lies on it; for every full vibration the circuit is once opened and again closed [einmal geöfnet und wieder geschlossen], and thereby are produced at station C in the core of the coil, just the same number of vibrations [ebensoviele schwingungen hervor-gebracht] which are there perceived as tones or as combinations of tones [accords]. By placing the cover tightly over the axis of the coil the tones at C are greatly strengthened. Besides the human voice [menlischen stimme] there can be reproduced (according to my experience) just as well the tones [töne] of good organ pipes from F to C and those of the piano; to that end the box *a* must be placed on the sounding board of the piano; out of thirteen chords a skilled experimenter could make out ten clearly. The telegraph apparatus placed on one side is evidently unnecessary for the reproduction of tones, but it is a very useful addition for convenient experimenting. With its aid it is possible to easily and surely make one's self intelligible [sich verständigen] with the person at the other station.

This may be done somewhat in the following simple manner: After the apparatus has been put up completely one satisfies one's self of the continuity of the connection and the strength of the battery by opening and closing the circuit whereby at A is heard a striking of the armature and at C a very perceptible ticking of the coil.

By a quick succession of makes and breaks at A, C is asked whether he is ready for experimenting, whereupon C answers in the same manner.

By agreement between the two stations simple signals can be given by opening and closing the circuit 1, 2, 3 or 4 times, *e. g.*, one stroke — sing: two strokes — speak, etc.

I telegraph words by numbering the letters of the alphabet and communicating their numbers.

1 stroke A,
2 strokes B,
3 strokes C,
4 strokes D,
5 strokes E, etc.

Z would consequently be indicated by 25 strokes.

But these numbers of strokes would take too much time and not be sure in counting. Therefore I put a dactyl for every 5 strokes, hence

— U U for E,
— U U and 1 stroke for F, etc.

Z: -UU-UU-UU-UU-UU, which is quicker, and more easily executed and better understood.

Still better is it to indicate the letters by numbers which are in inverse proportion to the frequency of their occurrence.

9 August, 1863, Friedrichsdorf, near Homburg, v. d. Höhe.

PHIL. REIS,
Teacher of A. L. Garnier's Boys' Institute.

No. 23. POLYTECHNISCHES JOURNAL OF DR. DINGLER, VOL. 169, p. 23.

[Put in evidence by Defendants. No. 28 in answer.]

(*This is a reprint of the Legat Article, No. 8, supra.*)

No. 24. BÖTTGER'S ACCOUNT OF REIS IMPROVED APPARATUS.

[Put in evidence by Defendants. No. 28 in answer.]

Dingler's Polytechnic Journal, Vol. 169, *p.* 399.

CONCERNING THE IMPROVED TELEPHONE.

In the meeting of the Physical Society, held on July 4th, at Frankfort a-M., a member of the society, Mr. Philip Reis, from Friedrichsdorf, near Homburg before the Heights, exhibited some of his improved telephones (Apparatus for the Reproduction of Tones at any desired distance by means of the Galvanic Current). It is two years since Mr. Reis first gave publicity to his apparatus, and although the performances of the same in their simple primitive form were astonishing, yet they had this great defect, that experimenting with the same was possible only for the inventor. The instruments exhibited in the above-mentioned meeting scarcely reminded one of the earlier forms.

Mr. Reis has striven to give the same a form pleasing to the eye, so that they now will worthily fill a place in every physical cabinet. This new apparatus can now be easily managed (worked) by every one, and works with great certainty. Melodies sung quite lightly at a distance of about 300 feet were reproduced by the instrument set up much more distinctly than formerly. The musical scale was especially sharply reproduced.

The experimenters could even reproduce words, although, indeed, only such as had been often heard by them.

In order now that others, less experienced, may be able to even make themselves understood through the apparatus, the inventor has fixed at the side of the same a small, yet, according to his explanation, entirely sufficient arrangement, whose speed of communication indeed is not so great as that of the more recent telegraphs, but which works very surely, and assumes no especial skill in the person working it. We would call the attention of gentlemen busying themselves with physics to the fact that the inventor now has this interesting apparatus manufactured for sale under his supervision (the principal [important] parts he makes himself), and the same can be had of him directly or through the instrument maker, Wilhelm Albert, at Frankfort-on-the-Main, in two qualities, differing only in outward finish, at 14 and 21 florins, respectively (Böttger's Polytechn. Notizblatt, 1863, No. 15).

No. 25. REIS IMPROVED APPARATUS.

[Put in evidence by Defendants. No. 26 in answer.]

Fortschritte der Physik, 1863, *p*. 96.

Ph. Reis Improved Telephone (DINGLER, CLXIX., 399.)

Herr Reis is said to have improved, quite essentially, his telephone. With the former instrument, experimentation was possible at the hands of the inventor himself, only.

The instrument (to be had at Albert's, in Frankfurt-a-M., for 14–21 fl.) has now, it is reported, a shape more pleasing to the eye, and can be operated easily by any one. At a distance of 300 feet tunes were reproduced far more distinctly than ever before. The scales are reproduced with peculiar precision. The experimenters were able even to communicate words, only such, however, as had been already often heard by them.

No. 26. GARTENLAUBE REIS IMPROVED APPARATUS.

[Put in evidence by Defendants. No. 35 in answer.]

(*The " Gartenlaube," No*. 51, *December*, 1863.)

THE MUSICAL TELEGRAPH.

The surprising results in telegraphing have often excited the question whether it may not be possible to communicate the language of sound itself to a distance. The trials made in this direction had till now produced no satisfactory results, because the vibrations of sound-conducting bodies soon diminish so much in force that they are no more perceptible for our senses.

People, perhaps, had already thought of a reproduction of sound at certain distances with the aid of the electric current, but those who have been the best fitted to attack the question, by their knowledge and resources, were the ones who doubted the most of a practical solution of that question. Those who are but superficially acquainted with natural science do not see the many difficulties this problem offers, if they are at all acquainted with it. Thus, about eleven years ago, a young man, Mr. Philip Reis, at present teacher of natural science at the Garnier Institute for Boys, at Friedrichsdorf, near Homburg, had the hardihood to work at the solution of this problem. But soon he was obliged to desist from it because his very first effort seemed to convince him of the impossibility of a solution. Later, however, after further studies and many experiments, he saw that his first effort was but a rudimentary one, and by no means convincing. However, he did not recommence to attack the question seriously for some time, not feeling himself strong enough to vanquish the obstacles on his road, although he never banished his early idea entirely from his thoughts.

How can a single instrument reproduce simultaneously "the combined effects of all the organs active in human speech?" This seemed to him the chief question. Later he put this question more methodically: "How does our ear perceive the composite vibrations of all the organs of speech acting at the same time?" or, expressed more generally, "How do we perceive the vibrations of several bodies sounding simultaneously?" If we throw a stone into quiet water there are produced on the surface uniform waves which progress symmetrically outward; the further they go the weaker they become, till they finally disappear.

It is quite similar with that what we call sound and tone. A body made to vibrate through any impulse affects the surrounding air, and causes waves in it, which follow each other at the same rate as the vibrations of the body. As those rings on the water consist in swellings and depressions, so also the vibrations of the air consist of alternate condensations and rarefactions. If they reach our ear every condensation presses the tympanum towards the interior of the cavity, and puts in motion the adjacent group of small bones which communicates the motion to the liquid of the cochlea, in which the auditory nerves terminate. The latter are excited and produce the *sensation of sound.*

Now, if the waves of vibration follow regularly and with a certain swiftness (sixteen in the second at least), we shall have the sensation of a musical *tone.* The latter is the *higher* the quicker the condensations follow each other and the louder the *stronger* or higher

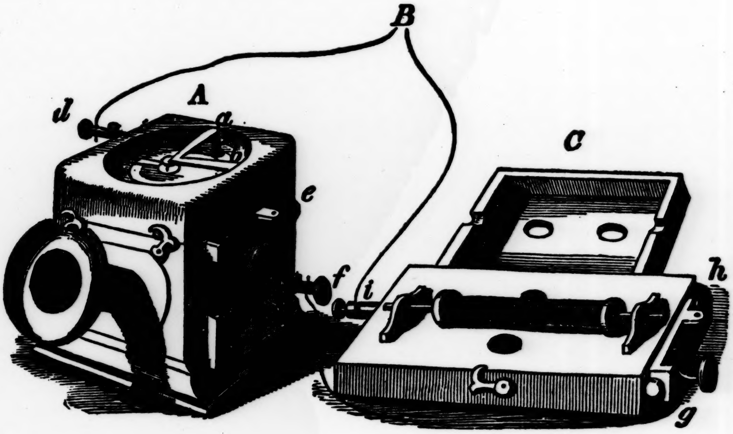
Our ear cannot peceive anything except condensations and rarefactions, wave crests and wave hollows. And, nevertheless, we receive the most varied auditory impressions, we distinguish the sound of the voices, we hear at the same time in quite different directions and can distinguish the different sources; nay, in a complete large orchestra, each of the numerous instruments is specially noticed by its peculiar sound, so that we decompose at every moment the total impression into its several parts, according to the height and depth, strength and weakness, or according to the timbre (or quality) [Klangfarbe].

Referring to our simile, this is about the same as if we throw two or more stones at different places into a calm pond. The wave lines cross each other, strengthen each other at some points, weaken each other at others, and the surface has a ruffled, hillocked aspect. But, nevertheless, our eye can detect the different systems of rings and can trace them back to their several causes. If we succeed in transmitting with the galvanic current the oscillations of a sounding body to a distance, so that there another body is put to equally rapid and, in respect to each other, equally strong oscillations, the problem of "telephoning" is solved.

For then exactly the same phenomena of waves are called forth on the distant points as the ear receives at the place of origin; therefore they also must make the same impression. The ear will distinguish at the distant points not only the single tones, according to their varying height and depth, but also to the proportionate force of the vibrations, and not only single melodies, but the performance of a whole orchestra; yes, even speech must be heard at the same time in places very distant from each other. Mr. Reis was the first one to prove by experiments the possibility of solving this problem. He has succeeded in constructing an apparatus to which he gives the name *Telephone*, and which enables one to reproduce tones, with the aid of electricity, at any given distance. Already, in October, 1861, he made rather successful experiments with a very simple, rudely made apparatus, before a numerous audience at Frankfort. On July 4th of the present year he presented an essentially improved apparatus at an assembly of the "Physical Union," which transmitted by closed doors and windows a melody sung moderately loud, to a distance of [illegible] feet, so that it could *be heard plainly.*

In order to give an opportunity to larger circles, especially to scientific men, to convince themselves of the efficiency of this essentially improved apparatus, Prof. Böttger of Frankfort-a-M. made lately (at an assembly of German physicists and doctors in Stettin, in the sectional meetings for natural sciences) several experiments which certainly would have been crowned with still more success if the hall in which the session was held had been located in a less noisy part of the city and filled with a less numerous audience.

Although, for the present, we are not so far along as to be able to converse with a friend at a distance of several hundred miles, so much at least is certain, that with the aid of the telephone songs of all kinds, melodies, especially in the middle registers, can be reproduced most clearly at unlimited distances. These wonderful results are obtained with the following simple apparatus, which we show here in one fourth of its size: —



A small box A (the telephone proper), a kind of hollow cube, has a mouthpiece S on the front side, and a somewhat smaller opening on the upper side of the box. The latter is closed with a fine membrane (skin from the intestines of a hog) tightly stretched. A narrow strip of platina *m*, connected with the screw post *d*, touches directly the membrane on its centre; a slender platina point *k*, attached to the angle *a b*, touches the strip of platina which rests on the membrane. If one sings into the mouthpiece S (by filling the same entirely with the mouth) the thin membrane vibrates and the attached platina strip receives likewise a vibrating motion so that it is alternately pressed against and leaves the platina point *k*.

From the binding post *d* which communicates with the platina strip resting on the membrane a conducting wire is connected with one of the poles of a galvanic battery B (about three to four sixnch Bunsen elements), and then the electricity is led through a wire attached to the second pole of the battery to the distant station C; there at *i* it passes through a coil *l l* formed of copper wire covered with silk thread, then back again to screw *f*, and there to the platina point *k*. At every vibration of the membrane an interruption of the electric current [unterbrechung des electrischen Stromes] takes place by the platina point parting from the platina strip.

Within the wire coil at station C is a thin iron wire (a strong knitting needle) which is about ten inches long, and which with its two ends projecting out of the coil for about 2 inches, each rests on two bridges of a sounding box. This is the *reproducing* apparatus.

At every interruption of the current [Unterbrechung des Stromes] in the coil the iron rod is made to vibrate. If the motions follow with a certain rapidity they produce a tone which is rendered audible by the sounding box. As the rate of the interruptions depends on the pitch of the tone that has been sung into the mouthpiece, the same tone is sounded with the same pitch from the sounding box. The length of the circuit has no influence upon this. It is true the electric current loses force the farther it goes, but there is no reason why relays should not be employed, the same as in telegraphing, and with their aid any number of reproducing apparatuses be set into simultaneous vibrations. Mr. Reis has endeavored to give to his improved apparatus a form which should also be pleasing to the eye, so that it might fill worthily its place in any physical laboratory. He has applied, moreover, to the side of the telephone, as well as to the reproducing apparatus, a small telegraph arrangement, which is a very good addition for convenient experimenting. (It is indicated in the drawing by the letters *e f h g*.) By alternately opening and closing the circuit with the key *e* or *h* the most varied signals may be given after mutual agreement; for instance, if one is ready for singing; if everything has been understood; whether one should stop singing or commence anew, etc.

Mr. Reis himself manufactures the principal parts of the telephone, for which no small amount of physical knowledge and experience is necessary. The mechanician, Wilhelm Albert, at Frankfort, is charged with manufacturing the less important parts and the external outfit, as well as with the sale of the instrument at a low price.

No. 27. COSMOS DESCRIPTION OF REIS.

[Put in evidence by Complainants.]

"*Cosmos,*" *Vol. XXIV., pages* 349, 352. *Printed and published at Paris, March* 22, 1864.

GENERAL PHYSICS: ACOUSTICS.

The Acoustic Telegraph or Telephone of Mr. Philip Reis.

In 1837 Mr. Page observed for the first time the phenomenon of the production of sound by electricity, when the poles of a magnet were rapidly brought near to and moved away from a helix or conducting wire through which an electrical current was passing. M. Delezenne produced an analogous effect by turning an armature of soft iron before the poles of a magnet. The particular phenomenon with a helix was observed separately by M. de la Rive and MM. Beatson and Marriani. Each of these physicists made upon this subject their own special remarks. M. de la Rive attributed the sound produced to the kind of shock which took place upon the sudden displacement of the molecules at the moment when the current produced its appropriate action. It would therefore be possible to increase the intensity of the effect produced by multiplying the intermittences in the passage of the current. It is in this way that the learned professor of Geneva was able to produce a sound both clear and prolonged, from a cylindrical mass of iron ten centimetres in diameter and weighing ten kilogrammes. M. Marriani recognized, on his part, that the sound created by a bar of iron placed in these conditions was the same as that which it would give forth if it was thrown into vibration by blows which affected it at its extremity. None of the magnetic metals produced any effect of the kind. As to the coercitive force, M. Marriani establishes that a bar of steel, well tempered, would make no sound, but that on the contrary the phenomena manifested itself when it was annealed. M. Marriani and M. de la Rive observed also that an intermittent current passed through a stretched wire made it produce a sound identical with that which it would give forth if it were placed in the interior of a helix. According to M. de la Rive the sound was more intense as the wire was made shorter and according as its electrical resistance came nearer to that of the battery employed.

M. Wertheim rendered sensible to the ear the vibrations which result from the passage of a discontinuous electric current through a rigid bar.

In these various experiments, in addition to the musical sound, the observer perceived a succession of blows (*battement*) which coincided with the interruptions of the current. M. de la Rive compared them to the noise which drops of rain made on falling upon a metal roof. These successive blows would even be obtained on operating upon magnetic metals reduced to a powder. M. de la Rive explains this: the sound produced by iron when the current passes in the magnetizing helix is explained by M. de la Rive as follows: —

"The current tends to place the molecules of the iron in a longitudinal direction; these tend to return afterwards to their normal position, hence the vibrational movement which gives rise to the sound."

It is on the basis of these facts that Mr. Reis has constructed the telephone or acoustic telegraph. Fantastic minds have singularly exalted the qualities of this apparatus; they have undertaken to indicate for it at once an office which it is far from being able to fill. The exaggerations of these illusions have been demonstrated to us by experiments which we have just made at Mr. Koenig's establishment with an apparatus constructed in Germany, under the supervision of Mr. Reis. This physicist has constructed his telephone in the following manner: —

The transmitter (manipulator) is represented by a rectangular hollow box. One of the sides of this is provided with a flaring opening, intended to receive the note which was to be transmitted. The upper surface of it consists of a membrane suitably stretched, on the centre of which is fixed a strip of platinum, which is in electrical connection with one of the poles of the battery. Above this there is placed a second and movable strip which, when the instrument is not in operation, rests on the first by a fine point, making contact by a fine point, also of platinum. It will readily be understood that if the membrane vibrates, it will throw up into the air the movable strip, which will again fall back into place. Hence oscillations which will correspond in number exactly with those of the membrane. The receiver is composed simply of a magnetizing helix, in the interior of which is placed a bar of soft iron; the whole is mounted on a resonating box. When the apparatus is to be operated, these two instruments are placed in the circuit with an ordinary line battery. The operation of the instrument is easy to understand. The vibrations which the operator placed in front of the mouthpiece impresses upon the air enclosed in the box of the transmitter are repeated by the membrane; and just as a style fixed on this membrane (as in the phonautograph) would write these vibrations upon a paper covered with lampblack, so in the same manner the electrical contacts are successively established and broken between the two strips of platinum. Hence, there is caused in the coil of the receiver a number of intermittences or interruptions in the passage of the current, which is necessarily equal to the number of vibrations of the membrane of the transmitter. Now, since each intermittation causes one single shock, a series must necessarily produce a sound identical in pitch with that produced at the mouthpiece of the transmitter. Would not the telephone of Mr. Reis be an admirable instrument if it realized absolutely the promises which its theory holds out? Without prejudging the future, we must recognize that it has not yet done so. When one sings the musical scale at the transmitter, there needs an ear well trained to distinguish the sound repeated by the receiver in the midst of the vibrations which agitate it. For ourselves we have been only able to recognize the successive rise and pitch of these rapid roulades; but perhaps a trained musician would be able to recognize amongst them a dominant note. The model, however, of which we speak did not, and had in its construction several causes of error; and Mr. Koenig, so justly recognized in matters of acoustics, intends to study out the improvements of which this telephone is susceptible.

Let us mention some of the principal of these causes of error: It may be that the membrane will not at every moment vibrate with the same degree of amplitude, and this will consequently occasion sometimes a failure to make contact; if the sound produced by the operator at the transmitting end does not vary much, the contact may be prolonged. The remedy for this defect is in substituting for the voice of the operator a tuning fork, arranged to vibrate, for example, by a battery; then a note would be produced which would be better defined, but always very feeble. As to improvements which would be of a nature to render this telegraphic apparatus practicable, Mr. Koenig is well fitted to find them. We already know certainly that the intensity of the sound increases as a softer iron is used, because in that case the molecules have more freedom of motion than they had in the hardened iron or in steel. If the iron core is magnetized by the influence of a permanent magnet, or by another coil, its sound is more intense when the intermittent current is sent in such a direction as to produce a demagnetizing effect upon it, and it is less intense when the current is sent through the helix in such a direction as to increase the magnetism. The reason is, that in this last case the molecules are in advance, in a position already very near that which the current can compel them to take. Too much tension in the core also makes the sound more feeble, for the molecules having been already placed in a forced position, are less free to receive further motion. The electrical transmission of musical sounds is therefore a problem, of which the true solution has not been found; and all the magnificent promises which have been made and published on the subject of acoustic telegraphy seem to us still to belong to the region of illusions.

No. 28. CLIFTON'S DESCRIPTION OF REIS.

[Put in evidence by Complainants.]

Proceedings of the Literary and Philosophical Society of Manchester.
Published at Manchester, 1865.

PHYSICAL AND MATHEMATICAL SECTION.

NOVEMBER 10, 1864.

Joseph Baxendell, F. R. A. S., president of the section, in the chair.

Professor Clifton exhibited an acoustical electric telegraph by which a note, sounded at one end of the line, is reproduced at the other end.

He also pointed out the principles involved in the construction of this telegraph, viz.: —

First. The production of a sound whenever a current of sufficient strength commences to circulate around an electro-magnet, or ceases so to circulate.

Second. The vibration of a stretched membrane in accordance with a note sounded near it.

With respect to the second principle, Professor Clifton drew attention to the fact that the researches of MM. Bourget and Bernard, in agreement with the mathematical investigations of Poisson and M. Lamé, show that a given square membrane will *not* vibrate in accord with *any note*, as stated by Savart. As the same is probably true of circular membranes, such as that used in this telegraph, it follows that only certain notes are capable of being transmitted by one instrument.

No. 29. KOENIG'S DESCRIPTION OF REIS.

[Put in evidence by Complainants.]

From KOENIG'S "*Catalogue des Appareils d'Acoustique*,"
Paris, 1865, *page* 5.

29. TELEPHONE OF M. REIS. 60 FR.

This apparatus is intended to transmit sounds to a distance by means of electricity. It rests upon the fact demonstrated by the preceding apparatus. [*The preceding apparatus was the Wertheim coil and core, which Reis uses for a receiver.*]

At the first station the current traverses a little band of platinum, which is attached to a membrane in such a way as to follow all its movements, and of a very movable point, which rests lightly upon this membrane. At the other station the current traverses a coil, at the centre of which is a bar of soft iron. If now we produce before the membrane a sound which causes it to vibrate, each vibration in pushing away the point from the platinum plate will produce an interruption of the current. On the other hand, each making of the current will produce in the bar of soft iron at the second station a momentary and weak sound. It is the rapid and isochronous succession of these sounds, all acting as simple blows, which produce the continuous sounds that are heard. It is true that they are not of good quality and that they cease from time to time. This comes from the fact that the membrane does not vibrate equally well for all tones, and because the manner in which the vibrations determine the interruption of the current, by pushing the little point away from the plate, is far from being perfect.

No. 30. PISKO'S DESCRIPTION OF REIS.

[Put in evidence by Defendants. No. 38 in answer.]

PISKO. *Die neueren Apparate der Akustik. Vienna*, 1865, *pp.* 94 *et seq.*

[Page 94.] *a.* 51. *Principle of the Telephone of Reis.* The "Telephone" of Reis (Fig. 60) is related to the Membrane-Phonautograph. The round end *s* of a light strip of platinum *n.s* is fastened upon the membrane *m m* with wax in such a way that the strip of platinum can make all of the vibrations of the membrane with it. Very near to this end *s* of the strip of platinum *n s* is a platina point fixed so that it is touched by the strip of platinum as this vibrates with the membrane. If we suppose the outer end *n* of the platina strip and the platina point to be connected with the poles of a battery, then a current is established or broken by the vibration [page 95] of the membrane, according to its phases. A magnetic piece of clock-work or an electro-magnetic telegraph introduced in this circuit would transmit to a distance indications that some one was speaking, but they would, self-evidently, not be able to make known what was spoken.

b. It is well known that an iron wire, surrounded by strong galvanic currents frequently broken, is made to sound forth tones which may be longitudinal or transverse, or both at the same time. Reis introduced such an iron wire lying in a multiplying coil at the second station C. This produced tones, if the membrane was caused to vibrate by singing or talking into (S, Fig. 60) the hollow, cubical part A. In my experiments with the telephone the rod never changed its pitch even with the most different tones and sounds, and always produced only the rhythm of the words sung or spoken at S into the part A. The aria of the song sung into the instrument could generally be recognized from the rhythm. The experiments, with special reference to this, are recited in § 53. But this much is evident already, that time must yet elapse before the simultaneous concerts and singing productions so ardently hoped for by the newspapers. The apparatus of Reis is indeed a "Telephone," but not a "Phonic Telegraph." The only means of transmitting song and speech, and this only for moderate distances, is the old well known speaking tube. But the experiment of Reis can always be classed with the most beautiful and interesting of school experiments; and as the means for producing it are simple, the apparatus of Reis will surely soon find its way even into moderately endowed institutions. That the sounding of the wire in the telephone is not due to acoustic transmission can be shown by cutting the coil out of the circuit; the sounding ceases at once.

1. Reis's phonautograph was originally made of a wooden cube with a conical cavity. The smaller opening was covered with the membrane. A knitting needle was used as the sounding wire, which projected about 2 inches out of each side of the multiplying coil, and rested upon two bridges of a resonance box. The surrounding [page 96] coil consisted of six layers of fine wire. Fig. 60 shows the telephone as it is at present manufactured, according to the inventor's directions, by artisan Albert, in Frankfurt, and artisan Uanck [Hauck?], in Vienna.

2. Even though the telephone cannot be used to reproduce concerts, this can be accomplished for moderate distances by the resonance of solid bodies, in narrow limits, to be sure. Pepper, director of the Polytechnic Institute, formed at London for amusing sciences, gave such a concert (18 5) with Wheatstone's method. Four of Erard's harps stood upon the stage. Each had on its resonance board a short staff of pine 2 cm. thick.

By turning the harps on their axes this staff was made to touch an exactly similar one, which went into a deep cellar, and there was in contact respectively with the sounding board of a piano, of a violoncello, of a violin, and the mouthpiece of a clarinet.

As long as the resonance staffs touched, the concert was heard distinctly; but as soon as one or all the harps came out of contact with the sound-conducting staff, the music ceased. The character of the instruments played was, as a whole, preserved, only the violoncello tones being somewhat raspy.

52. *Particulars regarding the Telephone.*

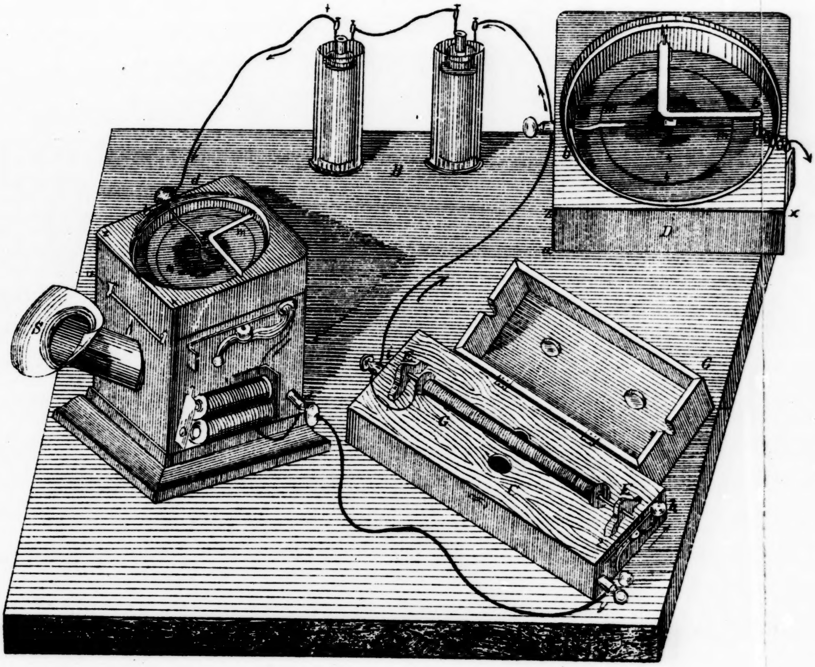
(*a.*) It consists subtantially of

1. The transmitter A.
2. The receiver C.
3. The battery B, and finally of
4. The conducting wires.

(*b.*) The transmitter A is essentially a parallelepipedic body of wood. Its upper part *u x* is cut out of one piece of square section, the side *z x* measuring 9 cm., its height *u x* 2.8 cm.

This part can be moved on the lower box A A by means of hinges. If we turn back the cover *x u* we shall notice a small circle cut out in it 3.9 cm. in diameter. A brass ring, with a margin 8 mm. broad, fits unto this hole, which is furnished with a groove like a pulley.

Over the ring the membrane *m m* is stretched by a silk thread lying in the groove of the same. This circular membrane is surrounded by a wider circular hollow $b\ b^1$ 8.5 cm. A shovel-shaped strip of platinum *n s* is placed in connection with the brass binding post *d*, and rests by its circular piece *s* on the centre of the membrane.


d
B
D
x
S
T
G
C
E
h

By means of sealing-wax this circular part is fastened to the membrane, and is thereby compelled to accompany the membrane in its vibration. The farther transmission of the galvanic current from t centre of the membrane takes place by means of the brass angle *a s b* (D, Fig. 60). This rests at *s*, by means of a platinum or steel point, upon the conducting platinum strip, *n s*, and dips at *b* with a platinum or steel point in a mercury cup which is made in a screw trans-ting the current. The point *a* serves only as a base or support for the angular piece *a s b*, which in general is supported like a tripod, in order that the contact point *s* should remain as constant as possible. The angle *a s b* is simply pushed over a projecting pin by a hole at *a*, until it remains resting on a broader lower part. From *b*, the electrical conductor with a covered wire extends to the brass key *e* (A, Fig. 60), and from there further in the direction indicated by the arrow.

The under part A A of the transmitter is constructed of wooden boards and form a parallelepipedon whose height = 6.8 cm., and whose breadth = 7.7 cm. For the reception of tones there is the slanting attachment S made of tin with a funnel-shaped enlargement. The longer side of this enlargement is 6.7 cm., the shorter 4.7 cm.; the vertical diameter of the enlargement measures 7.15 cm., the horizontal diameter 7.5 cm., and finally the diameter of the narrower cylinder 3.9 cm.

It is plain that, if necessary, the platinum strip can be replaced by a thin strip of brass, and the platinum or steel points by iron ones. Only then the contact points must oftener be cleaned to a metal polish.

(*c*.) The receiver is in general a double resonance box, whose upper part, "the cover," is movable on two hinges and can be laid back. The length of this cover is 16.4 cm., its width 9.5 cm., and its height 3.2 cm. The length of the under box measures 22.9 cm., its width 9.6 cm., and its height [98] 2.5 cm. The under part of the resonance box has two wooden bridges, which are separated from each other 7.4 cm., and serve as supports for the iron needle, which is 21.5 cm. long and 0.9 mm. thick, and intended to produce the tones. The length of the spiral placed over the needle and designed for producing the electro-magnetism is 15 cm. The wooden covers of both parts must be constructed as thin as possible, and the greatest breadth of the circular holes seen in the figure measures 13 mm.

(*d.*) One can successfully use as battery a small four-cell Smee's or two larger Bunsen's cells. The conducting line must be made at least so long that the exciting tones can no longer be heard through the wire. For corresponding between the two stations, the inventor has arranged the electro-magnetic telegraphic apparatus *e v g h*, easily seen and understood from the figure. Agreement can be easily had as to the corresponding signals, and it is simplest to accept the signs given by the inventor. (26.)

The receiver C gives, on tapping with the key *e*, the corresponding signals by the rod *e e* giving out tones, while at the transmitter A the electro-magnet *v* announces the signals by means of the spring armature *z*.

53. Experiments with the telephone.

(*a.*) As soon as one brings his mouth to the funnel S, and sings, the membrane of the transmitter A falls into corresponding vibrations, and the little iron rod *e e* at the second station begins to give out tones. Every time that a spark is visible at the first station, at *s*, the rod certainly sounds at the other station. The same is true when the peculiar buzzing tone is perceived, which arises from the striking of the vibrating platinum strip upon the point of the angular hook resting thereupon. The appearance of these sparks, or of the peculiar buzzing at the transmitter A, announces to the observers at the station A that the rod at C is giving forth tones. Tones and melodies, which were sung into the sound opening S, and especially clangs in which the teeth and head-bones also vibrate (the so-called humming tones), always produce a toning of the rod or needle E E, and indeed, as already mentioned (§ 51), without change of pitch, only with the reproduction of the rhythm of the respective song or words.

The pitch of the tone excited at C in the rod *e e* was, in the apparatus at my disposal, h': its strength not very remarkable and its quality [Klang] buzzing like that of the tone of a weak-sounding reed-pipe (something like a child's trumpet). The skin lying about the pericardium of the smaller and even the larger mammals (calves, etc.)

makes the best membrane, — gold-beater's skin reproduces only the lower tones.

The cover of the resonant box seemed superfluous in my apparatus, and the tone was indeed somewhat stronger without the cover.

1. In experiments with the telephone, close attention must be paid to seeing if the end *s* of the platinum strip still sticks to the membrane, and, if necessary, it must be pressed upon the membrane. When this leaf will no longer cling, a knife blade is heated, a piece of sealing-wax touched with it, and the melted wax thus transferred to the under side of the round end of the platinum strip *n s*. Immediately thereupon it is pressed on to the membrane *m m*.

2. From a long line of experiments, which I have performed with the telephone, I take the liberty of giving here some results: —

(*a.*) A Cagniard-Latour siren with upright axis, blown near the opening S from the lowest to the highest tone, gave no result. Only when the rotating plate was turned directly toward the funnel-shaped sound receiver S, and brought very near the same, was it twice possible with the medium tones of the siren to hear two short tones of the iron rod *e e* of the pitch h^1.

(*b.*) A tuning-fork with normal tone a^1 aroused no tone whatever in the receiver C, neither when in immediate vicinity of the sound funnel S, nor when laid upon it.

(*c.*) A metal bell, which gave, according as it was rubbed with a strong bow, the tone h^1 or h^2, produced no results from the telephone, even when the bell was brought ever so near to the sound reed S, or when laid upon it. Only when the tone h^1, by means of suitable resonant tubes was very perceptibly strengthened, did the telephone respond weakly and shortly, and indeed again with h^1.

(*d.*) Wooden lip pipes belonging to the scale between c^1 and c^2, when they were laid with the walls of their reeds on the sound funnel S and made to give out tones, were not able to bring the telephone to produce tones; but they were most active in respect to the telephone when the under open end of the reeds was brought immediately before or into the opening S of the sound cylinder of the transmitter A; this position may be called the "first."

These pipes also worked successfully upon the telephone, when their mouths (the holes) were laid on the sound-conducting opening S. This position may, from now on, be called the "second." If the pipes in both positions were removed only a few lines from the sound receiver S, the effective vibration of the membrane ceased, and, in fact, in the first position sooner than in the second. If, however, pipes of any material of different length (1 ft. to over 8 ft.) and different widths, were laid on the conducting sound tube, and the former pipes applied to these in the first or second position, the telephone gave the same results as in the immediate use of the short transmitting tube.

(*e*) The former pipes, when covered, caused (as was to be foreseen) the telephone mostly not to sound at all, or only interruptedly in the first position. In the second position the telephone was excited by them for the most part completely, seldom interruptedly.

(*f*.) I had at my disposal no pipes of the c^3 scale. Tones from the latter scale, which by strong blowing were excited in the pipes used by me, gave mostly no result, no matter what position was given to the pipe.

(*g*.) A reed-pipe of tone d^{-1} with open reed excited the rod of the telephone only when its open end was turned toward and brought near the sound-receiving funnel S of the transmitter. Increasing the tone by a resonant tube produced an interrupted tone. A like result was obtained with a reed-pipe of the tone c^{-1} with full beat reed, only here the excited telephone tone was constantly interrupted.

(*h*.) The miniature-normal-diapason (a small reed-pipe of the tone a^1 compare Chap. VI.) sunk into the sound-conducting reeds, so that the mouth lay on the funnel, produced a clear tone in the telephone when strongly blown.

(*i*.) Marches drummed at A with the key *e e* were produced by the receiver C, and in fact, always with the tone h^1.

(*k*.) Singing of different melodies was always successful; the rhythm of speaking was only interruptedly reproduced.

(*l*.) Whistling with the mouth into S had no effect, and the tone passed over into a higher one, probably because the vibrating column of air thereby became shorter. The tones f^1, g^1, a^1, fis^1, c^1 and cis^1, produced with the mouth by whistling passed over into fis^1, gis^1, b^1,

g^1, cis^1 and d^1 respectively, as soon as the mouth lay immediately before the sound receptor S.

There was a rise in tone of half a tone. Similar rise in tones is obtained by whistling into a cup, hat, etc. Indeed, the cutting off of the current of air coming from the mouth by the flat of the hand raises the tone in such whistling, and this can be very easily recognized by moving the hand up and down.

(*m.*) Since the distinct buzzing of the platinum strip on the transmitter S is a sure sign that the iron rod *e e* is sounding at C, there is no need in this respect of telegraphic communication between the stations (§ 52, d).

(*b.*) If a comparison is made of the results of experiments with the telephone and those with the membrane-phonautograph, it will seem at first as if the latter did much too little in comparison with the former. This contradiction, however, rapidly disappears. The membrane-phonautograph also gives plain tone writings of a melody in the space of an octave, together with double tones and chords, and according to Donders, still more. Moreover, in the telephone the membrane is moved not only by the vibrations of that tone, by which, according to the laws of sympathetic vibration, it can be brought into vibration, but it is also mechanically raised and lowered by the strong condensations and rarefactions arising from the exciting tone (singing, etc.) in the closed masses of air. Every condensation will press the membrane outward, even when its deepest normal tone is much higher than the exciting (sung) tone. Very strong and thick membranes might perhaps resist this purely mechanical excitation, but they would be then not sensitive enough for real sympathetic vibration. In many cases (for example, in drumming with the key on the box, in placing the apparatus A on the resonant cover of a piano, etc.) the vibration of the membrane in the telephone arises also only in the same way as the membrane in König's pipes for proving the nodes of vibration (compare a later paragraph). In this, also, the stretching of the membrane is not necessary in order that the latter may show outwardly the condensations and rarefactions of the air in the pipe.

Pipes with thin walls furnish a farther proof of this. The latter allow trembling to be felt when touched by the hand while the pipes are sounding; indeed, very thin walls deepen the tone somewhat, and thereby show that they are not able to resist the pressure arising from the condensations.

Sand sprinkled upon walls of this kind is thrown off from the nodal points. If, therefore, thin strips of wood are able to imitate in such a manner the vibrations of the air in the pipe, although the proper tone of the wall may lie far from the exciting tone, this is certainly much more the case with a membrane. The experiments with the pipes introduced in the previous paragraph also confirm this, for they only then gave a result in the telephone when the open end or mouth of the pipes lay very near the sound receptor, and even the experiments with singing confirmed this view. Just these experiments show the telephone weaker in comparison with the membrane-phonautograph, because in the latter, when the membrane is tuned for a tone, the tone-writing comes, whatever position the exciting tone may have had in reference to the sound-receiving side of the membrane-phonautograph, provided only it is near enough. And yet it would seem that to close the battery by means of the vibrating platinum strip on the membrane demands less strength than to move the little pen so that it may be able to remove the lampblack on the writing cylinder. The results of the few experiments with the telephone appear moreover to indicate that it might perhaps be more advantageous for the production of tone-writing by means of the membrane-phonautograph, to make the latter of smaller dimensions than has been the case up to the present. In fact, König is already busy on new arrangements for the membrane-phonautograph. König already hopes a better result for the written reproduction of simple sung melodies, if the wide opening of the paraboloid in the membrane-phonautograph be closed by a plate, which had a small opening for applying the mouth.

In any case, a renewed study of the laws of the sympathetic vibrations of the membrane with especial reference to both pieces of apparatus will be necessary. Many think that the membranes must vibrate sympathetically to every tone, because all the tones are heard by means of the membrane in the ear, but in this respect it is very important to note that, according to Prof. Mach (27), this may be brought about by a proper accommodation-mechanism in the ear.

For me this supposition of an accommodation, according to the varying tensions of the tympanum, has a high degree of probability bordering on certainty.

Philip Reis showed his apparatus for the first time in October, 1861, in a very primitive form to the Physical Society at Frankfort-on-the-Main; on July 4th, 1863, to the same society he showed the form represented in Fig. 60. This time he experimented over a distance of 300 ft. Prof. Böttger introduced the apparatus to the Naturforscher-Versammlung, at Stettin (1863), in the Physical Section.

No. 31. REIS PROSPECTUS—FROM PISKO.

[Put in evidence by Defendants. No. 39 in answer.]

PISCO'S *Neueren Apparate der Akustik, Wien*, 1865, *p*. 241.

26. Here may be the place for the prospectus which the inventor, Mr. Ph. Reis, attaches to the apparatus furnished by him and made by the artisan, Mr. Albert, in Frankfurt.

" *Telephon.*" Every apparatus consists, as can be seen from Fig. 60, page 96, of two parts, the telephone proper and the receiver C. These two parts are placed at such a distance from each other that the singing or toning of a musical instrument can be heard in no other way from one station to the other except through the apparatus.

Both parts are connected with each other and with the battery B like common telegraphs The battery must be sufficient to bring about at station A the attraction of the armature in the electro-magnet fastened at the side (3-4 six-inch Bunsen cells are sufficient for several hundred feet distance).

The galvanic current goes from B to the post *d*, from here through the copper strip to the platinum-leaf on the middle of the membrane, then through the foot (at D, Fig. 60) of the angle to the screw *b*, *in whose small hollow a small drop of mercury is placed.* From here the current goes through the small telegraph-apparatus *e f*, then back to the key of the station C and through the spiral over *i* back to B.

If now sufficiently strong tones are produced in front of the sound-opening S, through the vibrations of the same, the membrane and the angular-shaped little hammer lying upon it are set in vibration; the circuit is alternately opened and closed at every full vibration, and hereby are produced in the iron rod of the spiral at station C the same number of vibrations, and these are perceived there as tone or tone-combination (accords). By laying the upper box tightly upon the axis of the spiral the tones at C are very much strengthened.

Besides the human voice there can be produced (according to my experience) just as well the tones of good organ-pipes from F—c and those of the piano. For the latter purpose A is placed upon the sounding board of the piano. (Of thirteen common chords an experienced experimenter could clearly recognize 10.) As regards the telegraphic apparatus attached to the side, this is clearly unnecessary for the reproduction of tones, but it forms a very agreeable addition for comfortable experimenting. By this it is possible to correspond right well and surely with one's vis-à-vis.

This takes place somewhat tn the following simple manner:—

After the apparatus is completely set up assurance is had of the continuity of the conductor and the strength of the battery by opening and closing the circuit, when at A the striking of the armature and at C a very perceptible ticking of the spiral is heard.

By quickly alternately opening and closing at A it is asked at C if they are ready for experimenting, whereupon C answers in the same manner.

Simple signals can by agreement at both stations be given by opening and closing the circuit once, twice, three times, or four times, for example:—

1 stroke = sing,
2 strokes = speak, etc.

I telegraph words by numbering the letters of the alphabet and then communicating their numbers:—

1 stroke = a,
2 strokes = b,
3 strokes = c,
4 strokes = d,
5 strokes = e, etc.

z would in this way be designated by 25 strokes.

This number of strokes would, however, waste time in representing and would be difficult to count surely, wherefore I place a dactyl stroke for every five strokes, then we have,

—00 for e,

—00 and 1 stroke for f, &c.

z= —00 —00 —00 —00 —00, which is more quickly and easily carried out, and better to understand.

It is still better to designate the letters by numbers which are inversely proportional to the frequency of their recurrence.

No. 32. KUHN'S DESCRIPTION OF REIS.

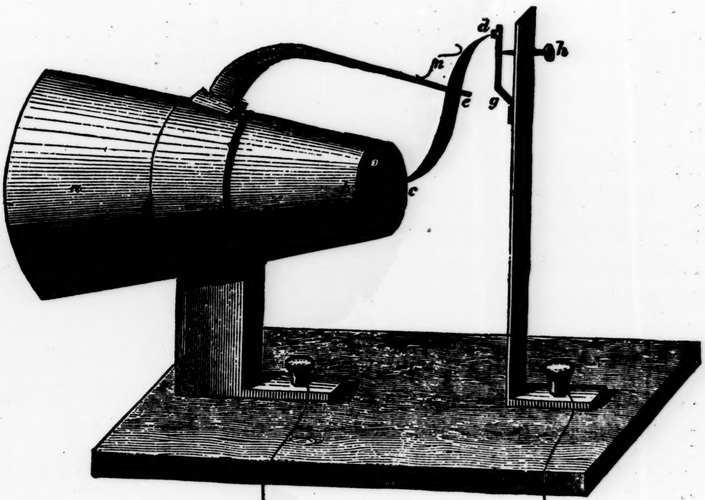
[Put in evidence by Complainants.]

Handbuch der Angewandten Elektricitätslehre VON KARL KUHN, 1865, *pp.* 1017–1021.

The experiments made by Reis in Frankfurt-a-M., on the 26th October, 1861, have proved, however, that when the breaks of the current [stromunterbrechungen] follow each other almost continuously and very quickly in a coil provided with a thin iron core, the iron wire can enter into longitudinal vibrations, and in this way be enabled to reproduce sounds of different pitch. An exact reproduction of the sounds does not take place, however, but only an imitation; for this reason it cannot be questioned here of transverse vibrations [transversal schwingungen]. A phenomenon [erscheinung] has otherwise been heard of, which belongs to the afore-mentioned class, in which the intensity and the timbre [klang] of the sound accompanying it (the phenomenon) depend among other things on the strength of the current [strom stärke] and on the number of breaks of the same, and in which, as it seems, the pitch of the tones also can vary under different circumstances. We can, however, hardly imagine by what arrangements it could be feasible to coax tones of any given height or depth out of an iron or metal tube split on one side, while it (the tube) is affected by the alternate currents of an induction apparatus the coil (rolle) of which surrounds it. Yet the possibility cannot be controverted that the principle of Neef's circuit breaker (unterbrecher) might contribute to the solution of the problem in question. It has been employed for local purposes either with or without modifications in the study and investigation of acoustic phenomena. Thus Petrina has used the principle of Neef's circuit-breaker [unterbrecher] for his electric harmonica in this way that instead of the Neef hammer a little rod was chosen, the transverse vibrations of which rendered the tone. "There are four little rods of various length side by side, the motions which are checked by means of levers managed by finger keys." That principle was used previously by Dove, in a modified manner, to set strained strings and elastic springs into acoustic vibrations of constant amplitude by means of an electric magnet, and, in this way, to be enabled to investigate constant tones. It appears from Legat's published communications that "the ideas submitted by Ph. Reis of Friedrichsdorf in the Physical Society and in the meetings of the German Hochstift in Frankfurt-a-M. about the reproduction of sounds by means of electricity" referred to arrangements of a similar kind. Legat mentions in his paper all that has been done thus far towards the realization of that project, and we borrow from it that part only which throws some light on the construction of a telegraphic apparatus with which it is said to be possible to produce vibrations and make sounds in any desired manner and through which the employment of electricity is said to make it feasible to bring forth at any given distance vibrations similar to the first produced ones and in this way to reproduce at a certain place tones originally produced at another place.

This apparatus is composed of a transmitter and of a receiver. The transmitter (Fig. 504, p. 1019) consists in a conical tube *a b* about 15 cm. long, 10 cm. at the front, 4 cm. at the back opening; the choice of the material as well as a greater length is indifferent; a greater width, on the contrary, is disadvantageous; the surface of the interior must be as smooth as possible. The narrower back opening is closed by a membrane of collodion *o*, and on the middle of the circular surface formed by this membrane rests one end *c* of lever *c d*, the fulcrum of which is held by a support and remains connected with the metallic circuit. This lever, one arm *c e* of which must be considerably longer than *e d*, should be as light as possible so as to follow easily the motions of the membrane, as an

FIG. 504.



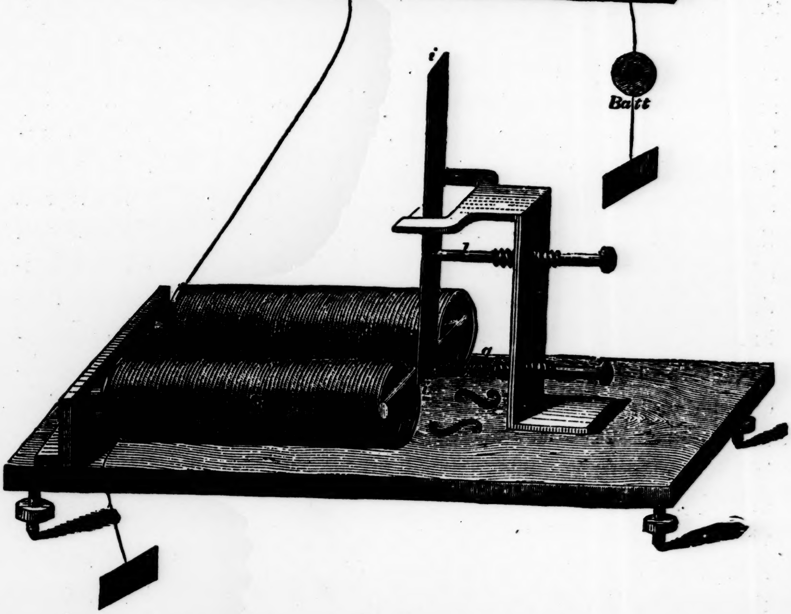


FIG. 505.

uncertain obedience [folgen] on part of lever *c d* would produce imperfect tones at the receiving station. In the state of rest, the contact *d g* is shut and a weak spring *n* holds the lever fast at rest. On the metallic support *f* which is connected with one of the poles of the battery is a spring *g*, with a contact which touches the contact of lever *c d* at *d* and the position of which is regulated by screw *h*; over tube *a b* a disk must be placed which encircles the outer circumference of the tube closely, so that the efficacy of the apparatus may not be impaired through the effect of the air waves coming round and striking against the rear end. This disk at right angles with longitudinal axis of the tube measures about fifty (?) cm. in diameter. The receiver (Fig. 505) consists of an electro-magnet *m m* which rests on a sounding board, and the coil of which is in connection with the metallic conductors, and with the ground. Opposite the electro-magnet is an armature connected with a lever as long as possible, but light and broad, which latter, with the armature, is fastened pendulum-like on the support *k*. Its motions are regulated through screw *l* or spring *o*. "In order to increase the efficacy of the apparatus, this receiver can be placed in one focus of an ellipsoidal enclosing box of suitable size, while the ear of the hearer is placed at the other focus." The working of the two apparatus (the mode of connection of which is visible in the woodcuts), the transmitter being placed at one station and the receiver at the other, is as follows: By speaking, singing, or the intromission of instrumental sounds into tube *a b*, in consequence of the condensation and rarefaction of the column of air, a motion of the membrane *c* corresponding to these changes is brought about. Lever *c d* follows the motions of the membrane, and opens or closes the circuit, according as a condensation or a rarefaction of the air inside takes place. As a consequence the electro magnet *m m* (Fig. 505) is correspondingly demagnetized or magnetized, and the armature affixed to it (as well as the armature lever) is set into similar vibrations as the membrane of the transmitter. Through lever *i* connected with the armature, similar vibrations are communicated to the surrounding air and (the increasing effect of the sounding board helping) the tones so produced finally reach the ear of the listener. In respect to the operations of this apparatus, the author remarks that the receiver does reproduce the exact number of the original vibrations, but that a reproduction of the original intensity has not yet been attained. For that reason, it is added, small differences in the vibrations are appreciated with difficulty, and in the practical experiments made thus far, it was possible to transmit with astonishing faithfulness chords, airs, etc., whilst in reading, speaking, etc., single words were more indistinctly heard. The apparatus just described is said to have been one of the constructions which Reis has used himself in his experiments. The underlying principles might give hopes of a farther improvement of the apparatus, but the telephone which, according to later reports, Reis has finally decided upon, has the disposition represented in Fig. 506, although the principle on which it is founded does not stand quite in harmony with the above-mentioned investigations of Wertheim, for instance.

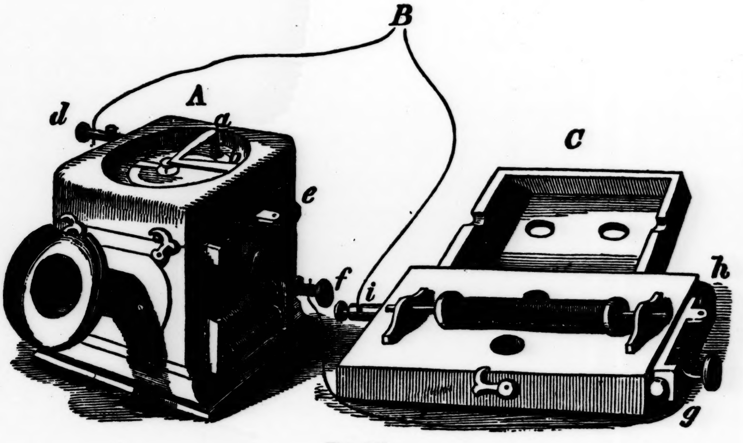


FIG. 506.

The telephone proper A consists of a hollow wooden box provided with a short sound funnel S and the upper side of which is open in the centre and covered over tightly with a delicate membrane. On the middle of the latter a thin platinum disk is fastened, from which on one side a platinum strip establishes circuit connection with the contact of the key at e, from which place the metallic connection is effected with one end of the coil of a small electro-magnet provided with a spring armature, whilst the other end is in contact with screw *f*. The reproducing apparatus C set up at the receiving station consists simply of a coil about six inches long formed by winding six layers of copper wire; in the axis of the coil a thin iron wire ten inches long (a knitting needle), protruding out of each end of the coil about two inches, is so disposed that with its bridge-like supports it rests on a sounding board. By means of screw *i* and of the key at *h g* the coil is thrown into the circuit and the connection of both apparatus is effected in the manner mentioned; a battery being placed at B, the course of the current is easily followed out. It can flow from B through *d c* and *c b* to *e* and *f*, and from here to the receiving station, and at *i* return to the battery, or it can start in the opposite direction according as *d* or *i* forms the starting point of the current. The circuit can be broken at will at each of the two stations by pressing the key lever, and a connection can be established thus in either direction, but the discontinuous currents which are to produce the sounding of the iron wire at C are obtained in this way: By singing or the blowing of instruments towards the sound funnel S the membrane at A is made to vibrate; if this can be brought about, it will happen, as was demonstrated by the experiments, that the iron wire of the receiver assumes isochronal vibrations, and whenever this is the case, it reproduces the same tones which set the membrane to vibrating at the transmitting station.

My own experiments have demonstrated that every melody starting from *c* and embracing the entire extent of an average male voice, when sung into the telephone can be reproduced by the receiver at C. The timbre [Klang] or quality of the sounds thus reproduced is not pleasant, — they are almost like the sounds of toy trumpets, at times also like the buzz of a fly caught in a spider's web and the like; yet the experiments of Reis are certainly interesting enough to challenge attention.

A reproduction of the words spoken into the telephone with or without variation of pitch was audible at the receiver only in a corresponding noise [entsprechendes Geräusch], while a discriminate perception of single vocal sounds, syllables or words could not be had. According to communications made on this subject by Reis, he has succeeded in reproducing the tones of organ pipes not covered, and those of a piano; in this latter case the transmitter was placed on the sounding board of the piano.

No. 33. HASSLER'S DESCRIPTION OF REIS.

[Put in evidence by Complainants.]

HASSLER'S *Technical Physics.* *Vienna,* 1866, *Vol. I., p.* 648.

The subject of phonotelegraphy will end this chapter. This rests upon a phenomenon first observed by Page, afterwards confirmed by Mariani, and more exactly studied and experimented upon by Wertheim; that is, that iron, under the influence of alternate magnetizing and demagnetizing by means of a galvanic helix, is set in longitudinal vibration and gives forth sound; and Reis showed beyond doubt the possibility of phonotelegraphy by means of an apparatus called by him telephone (Fig. 429), consisting of two parts, — the actual telephone (I), and the reproduction apparatus (II), used at the second station at a distance. Both parts are connected with one another and with a battery *s*, as in ordinary telegraphs. The battery *s* must be strong enough to work the armature *a* of the electro-magnets *e*, *e* (three or four six-inch Bunsen's elements are sufficient for a distance of several hundred feet). The current passes from *s* to the binding screw 2, thence through the strip of copper *n* into the disk of platinum *o*, resting on the middle of a thin circular membrane (hog's gut), stretched across the upper end of the wooden box *k*; afterwards it goes through the foot (platinum point) of the metallic angle *a*, *b*, *c* (this point standing on the disk *o*), into a vertical screw, provided with a small cavity at its upper end containing a drop of mercury, into which there dips from *a*, *a* a platinum point suspended above, while the angle *a*, *b*, *c* rests at *c* on a small metallic pillar, so as to be very easily made to vibrate about *a* and *c*. From this pillar (at *c*) the current goes through the key *t* and into the binding screw *i* connected with the wire leading to the pillar, thence through a wire stretched from this screw into the binding screw 3 on the apparatus 4, then through the key *t* of this apparatus into the bobbin *g* (magnetizing coil), inclosing the iron or steel wire *d*, *d* of the thickness of a knitting needle, into the binding screw 4, and finally thence by wire back to the second pole of the battery *s*. If, now, we produce sufficiently strong tones by means of organ pipes in front of the opening of the tube T (or sing them through the tube T in the hollow box *k*), the waves of the sound set the membrane *m* into regular vibrations. Every condensation occurring beneath *m*, at once raises the disk of platinum *o*, together with the platinum point *b* (the foot of the angle *a*, *b*, *c*); when the rarefaction occurs and *m* moves downward again, the angle *a*, *b*, *c* cannot immediately follow the disc *o*, and the current is interrupted, and a similar interruption occurs with every vibration of *m*, and in this way are produced just as many vibrations in the wire *d*, *d* of the coil *g*, at station II as the membrane makes; these vibrations are perceived there as tones and combination of tones (accords). These tones are much strengthened by covering the coils with a box of resonant wood, *d*, for a sounding board, so placed as to fit the sounding board, *b*, below. The keys X and X make it possible to communicate short messages as necessity arises, between stations I and II. (*E. g.*, to signify from II to I that they are ready to receive communications at II.) For by pressing down the keys the electro-magnet *e* is included in the circuit, the armature *a* drawn up and made to strike upon *e*.

The telephone is yet in its infancy, it is true, but even now, by employing powerful currents, it transmits at a distance not only solitary tones, but even tunes consisting of slow consecutive tones, quite perceptibly and distinctly.

No. 34. ALBERT'S CATALOGUE OF 1866.

[Put in evidence by Complainants.]

Catalogue of J. Wilh. Albert, *Mechanician at Frankfort-on-the-Main*, 1866.

[*Extract from preface.*] All instruments and apparatus will always be constructed according to the latest designs and improvements. In order that the construction may be better understood we have printed herein references where a description can be found as follows: —

M–P. Müller-Pouillet's Lehrbuch der Physik. vi Auflage. (Other books also named.)

From body of catalogue.

839. Telephone of Reis for reproduction of tones by electricity with description, 21 fl.

M–P. Fig. 325–327. Pisco, Akustik, Fig. 60.

840. The same in simpler design, fl. 14.

No. 35. FERGUSON'S DESCRIPTION OF REIS.

[Put in evidence by Defendants. No. 21 in answer.]

Extract from Publication entitled "Electricity," by Robert M. Ferguson, *London*, 1867. *Page* 257.

The Telephone. — This is an instrument for telegraphing notes of the same pitch. Any noise producing a single vibration of the air, when repeated regularly a certain number of times in the second (not less than thirty-two), produces, as is well known, a musical sound. In Art. 115, we found that when a rod of iron was placed in a coil of insulated wire, and magnetized by a current being sent through the coil, it gave out a distinct tick when it was demagnetized by the stoppage of the current. A person when singing any note causes the air to vibrate so many times per second, the number varying with the pitch of the note he sings, the higher the note the greater being the number of vibrations. If we then, by any means, can get these vibrations to break a closed circuit in which the coil just mentioned is included, the note sung at one station can be reproduced, at least so far as pitch is concerned, at another. Reis's telephone (invented 1861) accomplishes this in the following way: —

A A (Fig. 141) is a hollow wooden box with two round holes in it, one on the top, the other in front. The hole at the top is closed by a piece of bladder S, tightly stretched on a circular frame; a mouthpiece M is attached to the front opening.

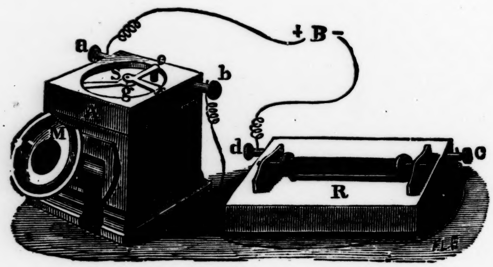


FIG. 141.

When a person sings in at the mouthpiece, the whole force of his voice is concentrated on the tight membrane, which in consequence vibrates with the voice. A thin strip of platinum is glued to the membrane, and connected with the binding screw *a*, in which a wire from the battery B is fixed. A tripod *e f g* rests on the skin. The feet *e* and *f* lie in metal cups on the circular frame over which the skin is stretched. One of these *f* rests in a cup containing mercury, and is connected with the binding screw *b*. The third foot *g*, consisting of a platinum point, lies on the circular end of the strip of platinum just mentioned. This point, being placed on the centre of the oscillating membrane, acts like a hopper, and hops up and down with it. It is easy to understand how, for every vibration of the membrane, the hopper will be thrown up for the instant from connection with its support, and how the close circuit is thus broken at every vibration. The receiving apparatus R consists of a coil of wire placed in circuit, enclosing an iron wire, both being fixed on a sounding box. The connections of the various parts of the circuit are easily learned from the figure. Suppose a person to sing a note at the mouthpiece which produces three hundred vibrations a second, the circuit is broken by the bladder three hundred times, and the iron wire ticking at this rate gives out a note of the same pitch. The note is weak, and in quality resembles the sound of a toy trumpet. Dr. Wright uses a receiving apparatus of the following kind: The line current is made to pass through the primary coil of a small induction coil. In the secondary circuit he places two sheets of paper, silvered on one side, back to back, so as to act as a condenser. Each current that comes from the sounding apparatus produces a current in the secondary circuit which charges and discharges the condenser, each discharge being accompanied by a sound like the sharp tap of a small hammer. The musical notes are rendered by these electric discharges, and are loud enough to be heard in a large hall.

No. 36. MÜLLER'S-POUILLET'S DESCRIPTION OF REIS.

[Put in evidence by Complainants.]

Lehrbuch der Physik and Meteorologie. Von Joh. Müller. Siebente Auflage, Zweiter Band, 1868, pp. 386-389.

Galvanisches Tönen.

After describing the production of tones by passing an intermittent current through the coil of an electro-magnet as practised by Wertheim and others, the author says: —

When the breaks [Unterbrechungen] of the electric current follow each other in quick succession, the pitch of the magnetic tone we have just mentioned is indeed not changed thereby; but there arises simultaneously another tone, which depends on the sum of the magnetic shocks [Stösse] which the iron atoms are subjected to, and has the same pitch as the tone offered by the breaking apparatus itself [Unterbrechungs apparat].

This tone, which arises by the side of the clicking noise, when the magnetic longitudinal tone of the rod is suppressed by the manner in which it is checked, is the one Reis made use of in the construction of his telephone.

Fig. 348 represents Reis's breaking apparatus [Unterbrechungs apparat]. In the cover of the wooden hollow cube A a circular opening is made, which is closed by an elastic membrane (Schweinsdünndarm, — hog's intestine) stretched over it. On the middle of this membrane a little platinum plate is cemented, which, through a very thin metallic strip *f* (more conspicuous in Fig. 349), is connected in circuit with screw *a*. On the middle of the platinum strip a short platinum point rests, which is fastened at *g* on the under side of the piece of metal plate *h g i*, one end *h* of which rests upon little

Fig. 348.

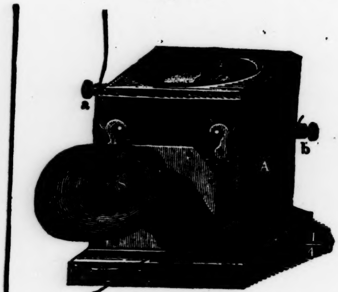


Fig. 349.

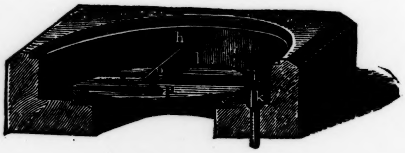
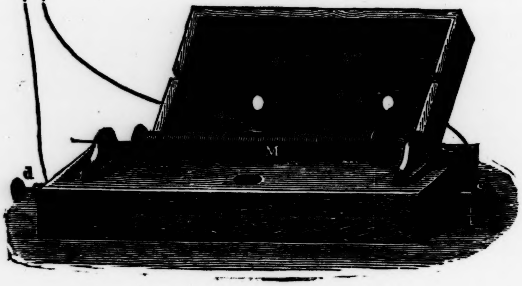


Fig. 350.



support *l*; whilst a platinum point fastened at *i* on its under side plunges in a hole of little metallic support *k*, said hole containing a small amount of quicksilver. Screw *b* is in electric connection with metallic support *k* [leitende Verbindung].

From one of the poles of the battery a conducting wire goes to screw *a* of the breaking apparatus [Unterbrechungs apparat], Fig. 348; from the other pole of the same a wire goes to screw *d* of the reproducing apparatus, to be mentioned next, Fig. 350. Screw *c* of this apparatus is connected through a wire with *b*, Fig. 348. Screws *c* and *d* are connected with the terminals of the small magnetizing coil M, Fig. 350. By the connection just mentioned the current of the battery passes through the coil.

Now as soon as the sound waves of a sufficiently strong tone get into the mouthpiece of wooden cube A, the elastic membrane which closes the top opening of the same is thrown into vibration. Every entering wave of condensation raises the platinum strip as well as the little point resting thereon, but when the membrane oscillates inwards, the metallic plate *h g i*, with the little point fastened on at *i*, cannot follow quick enough. There occurs then for every vibration of the membrane a break of the current [unterbrechung des stromes], which shows itself in a spark occurring at the point of breaking [unterbrechungsstelle]. Through the coil M runs a knitting needle, which, as the figure shows, is fastened on a sounding board. A cover provided with a second sounding board can be turned over the coil, and in this way the tone can be much increased.

Now, if tones are produced before mouthpiece *s* by singing into it or playing organ pipes, one hears at the reproducing apparatus, placed as far as convenient at first, a peculiar crackling noise which is independent of the pitch of the tones produced at the breaking apparatus, but, *besides these, tones themselves are distinctly and audibly reproduced by the steel wire;* and Reis found this to be true indeed for all tones between F and *f*.

In the experiments of Reis, the breaking apparatus was 300 feet distant from the coil; in fact it was placed in another house with closed doors. But as the length of the conductors can be extended just as far as in direct telegraphy, Reis gave to his apparatus the name "telephone" (*Jahres Bericht des Physicalischen Vereins zu Frankfurt-a-M., Für* 1860, 1861).

NO. 37. DR. VAN DER WEYDE'S REIS.

[Put in evidence by Defendants. No. 23 in answer.]

The Manufacturer and Builder, May, 1869.

THE TELEPHONE, BY DR. VAN DER WEYDE.

One of the most remarkable recent inventions connected with telegraphy is the telephone, an instrument which transmits directly the pitch of a sound by means of a telegraph wire, — either an air wire or submarine cable; so that, for instance, when the operator at one end of the wire sings or plays on an instrument any tune, as "Yankee Doodle" or "Hail Columbia," it will be heard and distinguished plainly at the other end. This invention may, in its present state, have no direct practical application, but be a mere scientific, although highly interesting curiosity; but who can say that it does not contain the germ of a new method of working the telegraph, or some other useful practical purpose?

The telephone is not the result of an accidental discovery, but of a thorough study of the laws of electro-magnetism and of sound. It is founded on the fact that the difference in pitch of different tones is caused by different velocities of vibrations of the elastic sounding body; which vibrations are transmitted to and by the air with exactly the same velocity, and from the air may be communicated to a properly stretched membrane, like a piece of bladder or very thin sheet of india rubber, stretched like a drum head, which these also will vibrate with exactly the same velocity as the air and the original sounding body, be it the human voice, organ pipe, string or any musical instrument. If, now, at the centre of this little drum head there be attached a small disk of some metal not easily burned by electric currents, — for instance, platinum, — while at the same time a platinum point may, by means of a screw, be so adjusted as to come very nearly in contact with this small platinum disk, it is clear that, when the membrane is put in vibration, a succession of contacts between the disk and point will be produced, of which the number in each second will exactly correspond with the number of vibrations in each second of the sounding body or the tone produced by it. That part of the apparatus which serves to send off the tune or melody is represented in the illustration, Fig. 2. It con-

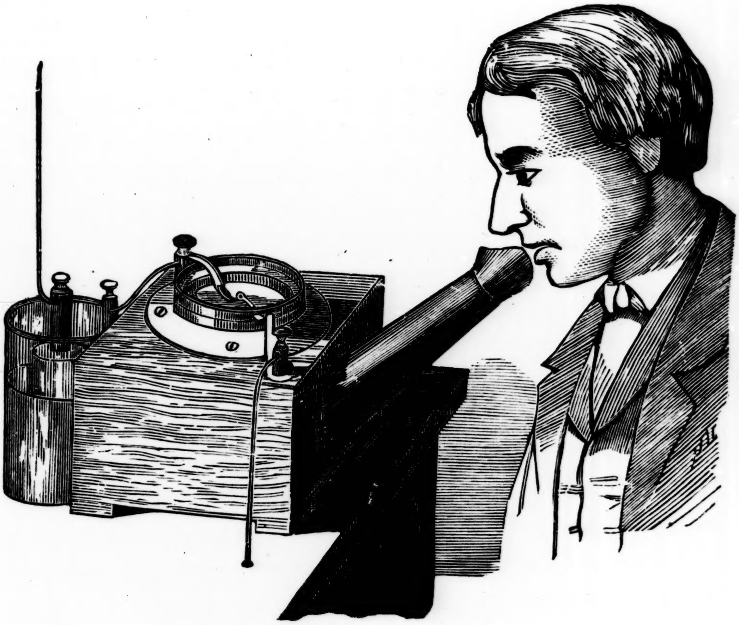


FIG. 2. — TRANSMITTING APPARATUS.

sists simply of a square wooden box, provided at the side with a kind of mouthpiece similar to that of a speaking tube, and at the top with an opening, over which the membrane just mentioned has been stretched. The small piece of platinum attached to the centre of this little drum head is, by means of a very flexible strip of some metal that conducts well, attached to one pole of the galvanic battery, of which only one cup is represented in the figure, although for a long wire several cups will, of course, be required. The reason why this connection near the platinum disk is a flat, thin and flexible strip is, that any rigidity would interfere with the freedom of vibration of the membrane to which it is attached. The point coming in contact with this small vibrating disk is connected with the ground wire, the other pole of the battery with the air wire or submarine cable. It is clear, from this explanation, that at every contact of the platinum point a wave of electricity will be sent over the wire, and as many waves in a second as there are contacts; and as there are as many contacts as there are vibrations in every second, the number of electric waves will be always exactly equal to the number of vibrations corresponding with the pitch of each tone, be it fifty, one hundred, two hundred or five hundred in every second.

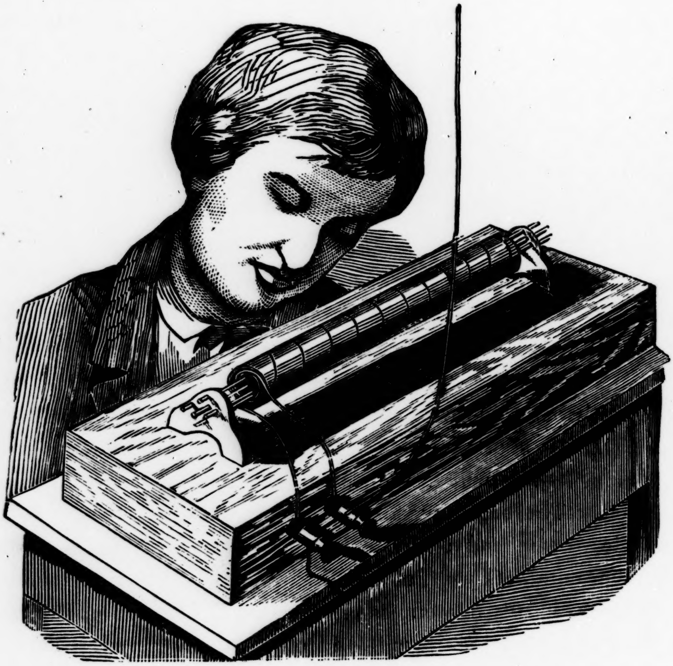


FIG. 3. — THE RECEIVER.

The instrument in which this succession of waves is made audible at the other end of the telegraph wire is founded on the fact — first investigated by Professor Henry, of the Smithsonian Institute at Washington — that iron bars, when becoming magnetic by means of electric currents passing around them, become slightly elongated, and at the interruption of the current are at once restored to their original length. It is represented in the cut, Fig. 3, and consists of an elongated wooden box, of which the top is made of thin pine wood, similar to the sounding board of a stringed musical instrument, to which are attached two bridges carrying long pieces of moderately thick and very soft iron wire, which, for nearly their whole length, are surrounded by a coil similar to the coil of the electro-magnets used in telegraphing. One end of this coil is attached to the telegraph wire, the other to the ground wire, as represented in the figure. At every instant that a contact is established at the station where the sound is produced, and a current wave thus transmitted, these wires will become magnetic, and consequently elongated; and they will be shortened again at every interruption of the current. And as these currents and interruptions succeed each other with the same velocity as the sound vibrations, the elongations and shortenings of the magnetized iron wires will succeed each other with exactly the same velocity, and consequently they will be thrown into a state of longitudinal vibrations corresponding with the original musical tone, which vibrations will then be communicated to the sounding board in exactly the same manner as is the case with the vibrations of the strings in all stringed instruments, thus becoming more audible at the receiving station.

It is clear, from the foregoing explanations, that no quality of tone can be transmitted. Much less can articulate words be sent, notwithstanding the enthusiastic prediction of some persons, who, when they first beheld this apparatus in operation, exclaimed that now we would talk directly through the wire. It is from its nature able to transmit only pitch and rhythm, — consequently melody, and nothing more. No harmony nor different degrees of strength or other qualities of tone can be transmitted. The receiving instrument, in fact, sings the melodies transmitted, as it were, with its own voice, resembling the humming of an insect, regardless of the quality of the tone which produces the original tune at the other end of the wire.

This instrument is a German invention, and was first exhibited in New York, at the Polytechnic Association of the American Institute, by Dr. Van der Weyde. The original sounds were produced at the farther extremity of the large building (the Cooper Institute), totally out of hearing of the association; and the receiving instrument, standing on the table of the lecture room, produced with its own rather nasal twang the different tunes sung at the other end of the line, rather weakly, it is true, because of the weak battery used, but very distinctly and correctly.

No. 38. THE TELEGRAPHER, VOL. V., No. 39.

[Put in evidence by Defendants. No. 22 in answer.]

(*This is a reprint of Dr. Van der Weyde's article, No.* 37, *supra.*)

NO. 39. AMERICAN ASSOCIATION ON REIS.

[Put in evidence by Complainants.]

Proceedings American Association for the Advancement of Science. Meeting at Salem, August, 1869.

In the list of papers read is the following: —

"On the audible transmission of musical melodies by means of the electric telegraph. By P. H. Van der Weyde."

[*Article not printed in the proceedings.*]

NO. 40. AMERICAN ASSOCIATION ON REIS.

[Put in evidence by Complainants.]

Boston Daily Advertiser of Aug. 25, 1869.

REPORT OF MEETING OF AMERICAN ASSOCIATION, AT SALEM.

Prof. Van der Weyde exhibited the "telephone," an instrument for the audible transmission of musical melodies, by means of the electric telegraph. The system is fully described in the May number of the *Architect and Builder*.

The apparatus to accomplish this is called a telephone. By means of it the operator at one end of the wire sings or plays on an instrument any tune, and it can be heard and plainly distinguished at the other end. The exhibition of the instrument excited much interest.

No. 41. BAILE'S ARTICLE.

[Put in evidence by Defendants. No. 24 in answer.]

[*The Wonders of Electricity. Translated from the French of J. Baile. New York: Scribner, Armstrong & Co.* 1872. *pp.* 140–143.]

Wonderful as are these achievements, the inventions in telegraphy have gone still further. To be able to transmit thought to a distance is a triumph which was formerly astonishing; but we are now accustomed to it, and continue to practise it without its creating the slightest wonder. To be able to transmit handwriting and even drawings appeared to be still more difficult; but this problem has also been resolved, and we now hardly wonder that this feat is accomplished by means so simple. Mankind ever requires a new stimulus to its curiosity, and already it is looking forward to the discovery of more marvels in telegraphy. Some years hence, for all we know, we may be able to transmit the vocal message itself, with the very inflection, tone and accent of the speaker. Already has the acoustic telegraph been invented; the principle has been discovered, and it only remains to render the invention practicable and useful, a result which, in these days of science, does not appear to be impossible.

Sound, of whatever kind, is produced by a series of vibrations, more or less rapid, which, setting out from a sonorous body, traverse the air and reach our ear. Just as a stone dropped into a pond throws off a succession of circular undulations or water rings, so a concussion, acting on the air, produces analogous vibrations, though they are invisible; and it is when these vibrations reach the ear that we become sensible of sound.

An eminent scientific German, M. Helmholtz, has analyzed the human voice and determined its musical value. According to him each simple vowel is formed by one or more notes of the scale, accompanied by other and feebler notes, which are harmonics of these. He demonstrates that it is the union of all these notes that give quality to the voice. Each syllable is formed by the notes of the vowel accomplished by different movements of the organs of the mouth. M. Helmholtz, reflecting upon this, thinks it would be possible to construct a human voice by artificially producing and combining the elementary sounds of which it is composed. This is not the place to discuss such theories, but if we grant that there is any truth in them, we can understand that the acoustic telegraph can be invented, and can transmit the living voice. Already experiments have been made in this direction. A vibrating plate produces a sound, and according to the rapidity of the vibrations, these sounds are sharp or flat. At each of the vibrations the plate touches a small point placed in front of it, and this contact suffices to throw the current into the line; when the plate ceases to vibrate and returns to its position of equilibrium, it no longer touches the metal point and the current is consequently interrupted. By this means is obtained a series of interruptions, more or less rapid, according to the sound; the current being thrown into the line and interrupted once for each of the vibrations.

At the extremity of the line the current enters an electro-magnet which attracts another vibrating plate of size and quality identical with the former. Attracted and repelled very rapidly, exactly, and as rapidly, in fact, as the plate mentioned above, this second plate gives forth a sound which will have the same musical value as that of the other, as the number of vibrations per second is the same in both cases.

Should this process be perfected it will be possible to transmit sound by means of the telegraph, to transmit a series of sounds, a tune, or spoken sentence and conversation. This consummation has not, however, been yet attained. Many experiments have been made, the principle has been applied in divers ways, and everything makes us hope that we will yet arrive at a perfect system of acoustic telegraphy. Advances have been made very far upon the road to success. A series of vibrating plates, answering to the strings of a harp, has been arranged, each of which vibrates when struck by a particular sound, and sends off electricity to create at the end of the line the same vibrations in a corresponding plate, or, in other words, to produce the same sound.

This system it must be admitted, is at least very ingenious. Experiments have been made in laboratories, that is to say, under conditions entirely favorable, and such as we would not often find in actual practice. Under these conditions a musical air has actually been successfully transmitted by this acoustic telegraph. All must admit that this is a promising beginning; but we must not make too much haste to exalt the miracle and to extol the advantages of the future machine, or to abandon ourselves to the indulgence in indiscriminate laudation on the strength of this new discovery. That would be a gross mistake and an injury to science. True scientific faith is doubt, until the truth appears in uncontrovertible clearness. Care must be taken not to take for reality that which is merely a desire on our part. We must guard against all premature exultation, because it weakens us in the search for truth, and because even one deception is cruel. Let us therefore give to doubt, to patience and to perseverance the place which some too readily give to congratulation.

No. 42. ALBERT'S CATALOGUE OF 1873.

[Put in evidence by Complainants.]

Catalogue of J. WILH. ALBERT, *mechanician, at Frankfort-on-the-Main*, 1873.

[*Extract from Preface.*] All instruments and apparatus will always be constructed according to the latest designs and improvements. In order that their construction may be better understood, we have printed herein references where a more complete description can be found as follows: —

M.-P. Müller-Pouillet's Lehrbuckder Physik VII Auflage.

A list of other books is given.

In the body of the catalogue is the following: —

957. Telephone of Reis for reproduction of tones by electricity, with description, 21 florins, 36 Rm.

(M.-P. fig. 348, bis. 350: Pisco, Akustik, fig. 60.)

958. The same with a simple electro-magnetic signalling apparatus. 26 fl. 15 kr.—45 Rm.

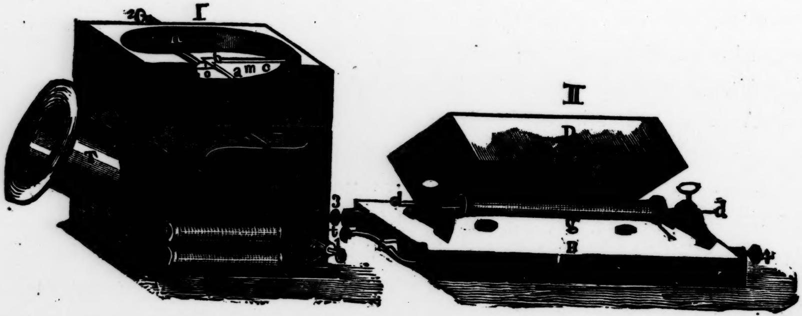
NO. 43. DR. VAN DER WEYDE'S SECOND ARTICLE.

[Put in evidence by Complainants.]

Scientific American, March 4, 1876.

THE INVENTION OF THE TELEPHONE. BY P. H. VAN DER WEYDE, M. D.

In connection with Mr. Gray's application of the telephone to the simultaneous transmission of several different telegraphic messages over one wire at the same time, and his paper read before the American Electrical Society (published on page 92, *Scientific American* supplement for Feb. 5), it may be interesting for the readers of this paper to obtain some information in regard to the invention of the telephone, by Reuss. As mentioned in the article above referred to, Page and Henry observed that, by rapid magnetization and demagnetization, iron could be put into vibrations isochronic with the interruptions of the current; and later, Marian experimented extensively in this direction, while Wertheim made a thorough investigation of the subject, which induced Reuss, of Friedrichsdorf, near Hamburg, Germany, to apply this principle to the transmission of musical tones and melodies by telegraph; and he contrived an apparatus which we represent in the engravings.



PROFESSOR REUSS'S TELEPHONE.

The telephone of Reuss consists of two parts, the transmitting and the receiving instrument. Fig. I. represents the former, and is placed at the locality where the music is produced; Fig. II., the latter, is placed at the station where the music is to be heard, which may be at a distance of 100, 200, or more miles, in fact, as far as the battery used can carry the current; while the two instruments are connected with the battery and the telegraph wire in the usual manner. One pole of the battery is connected with the ground plate, the other with the screw, marked 2 in our Fig. I., and thence over a thin copper strip, *n*, with the platinum disk, *o*, attached to the centre of the membrane stretched in the large top opening of the hollow and empty box, K, intended to receive and strengthen the vibrations of the air, produced by singing before the funnel-shaped short tube attached to the opening in T. Over the platinum disk, *c*, attached to the elastic membrane, is a platinum point attached to the arms, *b c* and *b* K, while a set screw brings this point in slight contact with the platinum disk mentioned. A part of the box is represented as broken and removed, in order to show the internal construction. The strip, *a b c* is connected with the end, *s*, of the switch *t s*, and the screw connection, 1, at the lower right-hand corner, and also through the telegraph wire, to the instrument Fig. II., at the receiving station, which may be situated at a distance of many miles. Here the current enters by the screw connection, 3, and passes through the spiral *g*, surrounding the soft iron wire, *d d*, of the thickness of a knitting needle, and leaves the apparatus at the screw connection, 4, whence it obtains access to the ground plate, and so passes, through the earth, back to the battery. The spiral and iron wire, *d d*, is supported on a hollow box, B, of thin board; while a cover, D, of the same material is placed on top, all intended to strengthen the sound produced by the vibrations which the interruption of the current caused in the iron wire, *d d*, so as to make these vibrations more audible by giving a large vibratory surface, in the same way that the sounding board of a piano-forte strengthens the vibrations of the air caused by the strings, and makes a very weak sound quite powerful.

If a flute be played before the opening, T, or if a voice be singing there, the vibration of the air inside the box, K, causes the membrane, *m*, to vibrate synchronically, and this causes the platinum disk, *o*, to move up and down with corresponding frequency. At every downward motion the contact of this disk with the platinum point, under *b*, is broken, and therefore the current is interrupted as rapidly as the vibrations occur. Let, for instance, the note C be sounded; this note makes sixty-four full vibrations in a second, and we have, therefore, sixty-four interruptions of the electric current, which interruption will at once be transmitted through the telegraph line to the receiving instrument, and put the bar *d d* into exactly similar vibrations, making the very same tone, C, audible; and so on for all other rates of vibration. It is clear that in this way not only the rhythm of music can be transmitted (and this can be done by the ordinary telegraph), but the very tones, as well as the relative durations and the rests between them, can thus be sent, making a full and complete melody. The switch, *t s*, Fig. I., is intended, in connection with a similar one in Fig. II., to communicate between the stations, with the help of the electro-magnet, E E, to ascertain if station, Fig. II., is ready to receive the melodies; then it gives the signal, by manipulating the switch, which is received by the attraction of the armature, A, the latter arrangement being a simple Morse apparatus, attached to the telephone.

Professor Heisler, in his "*Lehrbuch der technischen Physik*" (3d edition, Vienna, 1866), says, in regard to this instrument: "The telephone is still in its infancy; however, by the use of batteries of proper strength, it already transmits not only single musical tones, but even the most intricate melodies, sung at one end of the line to the other, situated at a great distance, and makes them perceptible there with all the desirable distinctness." After reading this account in 1868 I had two such telephones constructed, and exhibited them at the meeting of the Polytechnic Club of the American Institute. The original sounds were produced at the further extremity of the large building (the Cooper Institute), totally out of hearing of the Association, and the receiving instrument, standing on the table in the lecture room, produced (with a peculiar and rather nasal twang) the different tunes sung into the box, K, at the other end of the line; not powerfully, it is true, but very distinctly and correctly. In the succeeding summer I improved the form of the box, K, so as to produce a more powerful vibration of the membrane, by means of reflections effected by curving the sides; I also improved the receiving instrument by introducing several iron wires in the coil, so as to produce a stronger vibration. I submitted these, with some other improvements, to the meeting of the American Association for the Advancement of Science, and on that occasion (now seven years ago) expressed the opinion that the instrument contained the germ of a new method of working the electric telegraph, and would undoubtedly lead to further improvements in this branch of science, needing only that a competent person give it his undivided attention, so as to develop out of it all that it is evidently capable of producing.

Before leaving this subject I wish to draw special attention to the fact that the merits of this invention consist chiefly in the absence of musical instruments, tuning forks, or their equivalents, for producing the tones; any instrument will do; flute, violin, human voice, etc. If the aerial vibrations are only conducted into the box, Fig. I., the apparatus will send the pitch as well as the duration of the different tones, with the rests between, therefore not only transmitting perfect rhythm, but a complete melody, with its long and short notes. The two parts of the apparatus may even be connected each to a separate piano-forte; and if this were done in a proper manner a melody played on the piano-forte connected with the transmitting instrument, Fig. I., would be heard in the piano-forte at a great distance, connected with the receiving instrument, Fig. II.

No. 44. SOUTH KENSINGTON REIS.

[Put in evidence by Complainants.]

(*Title-page of the German Work.*)

Report of the Exhibition of Scientific Apparatuses in South Kensington Museum, London, 1876. *Also a complete and descriptive catalogue of the Exhibition with engravings, ordered by the Royal Council of Education. Arranged by Dr. Rudolf Biedermann, London,* 1877.

P. 188. Group 6. *Sound.*

922. Telephone, after J. Reis, for the reproduction of tones by electricity, J. W. Albert, Frankfort-a-M.

The telephone is based on the experiments of Wertheim and others on galvanic sounds. Philip Reis of Friedrichsdorf made use of this for the reproduction of musical tones produced by singing (wind instruments, etc.) by way of electricity with the aid of an elastic membrane and a breaking apparatus constructed by him. (Vide annual report of the Physical Society of Frankfort-a-M., of 1860–61: also Müller's Lehrbuch der Physick VII. Ed., 2d. Vol. p. 135.)

No. 45. PREECE ON REIS.

[Put in evidence by Complainants.]

Report of the Forty-seventh meeting of the British Association for the Advancement of Science, held at Plymouth in August, 1877.

On the Telephone. By W. H. PREECE, *Memb. Inst. C. E., etc.*

Philip Reis, of Friedrichsdorf, in 1861, produced the first telephone which reproduced musical sounds at a distance. He utilized the discovery of Page by causing a vibrating diaphragm to rapidly make and break a galvanic circuit. The principle of his apparatus is shown in Fig. 1 annexed, in which the diagram (*b*) is a hollow wooden box into which the operator sings through the mouthpiece (*a*).

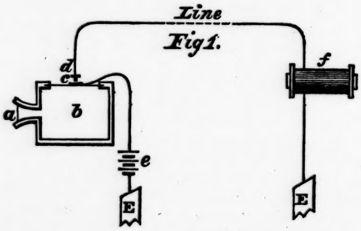


Fig 1.

The sound of his voice throws the diaphragm (*c*) into rapid vibration, so as to make and break contact at the platinum points (*d*) at each vibration. This interrupts the current flowing from the battery (*e*) as often as the diaphragm vibrates, and therefore magnetizes and demagnetizes the electro-magnet as often. Hence whatever note be sounded into the box (*a*) the diaphragm (*c*) will vibrate to the note, and the electro-magnet *f* will similarly respond, and therefore repeat that note.

Musical sounds vary in tone, in intensity and in quality. The tone depends on the number of vibrations per second only; the intensity on the amplitude or extent of those vibrations; the quality on the form of the waves made by the vibrating particles of air.

It is evident that in Reis's telephone everything at the receiving end remains the same, excepting the number of vibrations, and therefore the sounds emitted by it varied only in tone, and were therefore notes and nothing more. The instrument remained a pretty philosophical toy, and was of no practical value.

Cromwell Varley, in 1870, showed how sounds could be produced by rapidly charging and discharging a condenser.

No. 46. GANOT'S DESCRIPTION OF REIS.

[Put in evidence by Complainants.]

GANOT'S *Elementary Treaties on Physics. 8th Edition, Translated by* E. ATKINSON. *N. Y.*, 1877, *p.* 757.

Reis's telephone consists essentially of a membrane which is put in vibration by producing musical sounds in front of a convenient mouthpiece. The apparatus is so arranged that these vibrations alternately open and close a current which produces at any distance sounds by such an arrangement as the above.

DOLBEAR ON REIS.

[Put in evidence by Complainants. Record, p. 426.]

The Telephone, by Prof. A. E. DOLBEAR. Boston: Lee & Shepard, 1877. pp. 99-116.

Having treated at some length of the three factors involved in telephony, — namely, electricity, magnetism, and sound, — it remains to follow up the various steps that have led to the actual transmission of musical sounds and speech over an ordinary electric circuit.

It is stated upon p. 31, that, when a current of electricity is passed through a coil of wire that surrounds a rod of soft iron, the latter is made a temporary magnet; it loses its magnetic property the instant that the current ceases. If the rod be of considerable size, say a foot or more in length, and half an inch or more in diameter, and the current be strong enough to make a powerful magnet of it, whenever the current from the battery is broken, the bar may be heard to give out a single *click*. This will happen as often as the current is broken. This is occasioned by a molecular movement which results in a *change* of *length* of the bar. When it is made a magnet, it elongates about $\frac{1}{25000}$ of its length; and, when it loses its magnetism, it *suddenly* regains its original length; and this change is accompanied with the sound. This sound was first noticed by Professor C. G. Page, of Salem, Mass., in 1837. If some means be devised for breaking such a circuit more than fifteen or sixteen times a second, we shall have a continuous sound with a pitch depending upon the number of clicks per second. Such a device was first invented by the same man, and was accomplished by fixing the armature of an electro-magnet to a spring which was in the circuit when the spring was pressing against a metallic knob, at which time the current made the circuit in the coil of the electro-magnet. The magnet attracting the armature away from the button broke the circuit, which of course destroyed the magnetism of the magnet, and allowed the spring to fly back against the button, to complete the circuit, and reproduce the same series of changes. The rapidity with which the current may be broken in this way is only limited by the strength of both spring and current. The greater the tension of the spring with a given current, the greater number of vibrations will it make.

Suppose such an intermittent current to pass through the coil surrounding the soft iron rod 256 times per second; then the rod would evidently give 256 clicks per second, which would have the pitch of C. When these clicks are produced in the rod held in the hand, the sound is hardly perceptible, being like that of a sounding tuning-fork when held thus. In order to strengthen it, it is necessary to place it on some resonant surface. It is customary to mount it upon an oblong box with one or two holes in its upper

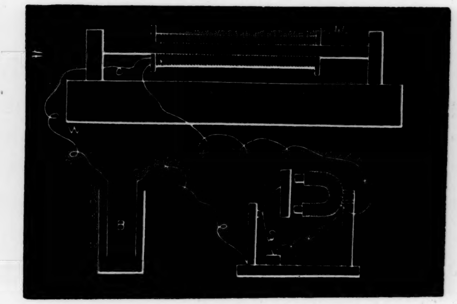


FIG. 11.

surface, inasmuch as such a form is found to give a louder response than any other, and is the shape usually given to æolian harps. The accompanying cut shows the combination of battery B, the circuit-breaker, and the rod mounted upon the box. The wire W may evidently be of any length, the magnetized rod and box responding to the number of vibrations of the spring S, how long soever the circuit may be.

HELMHOLTZ'S ELECTRIC INTERRUPTOR.

In some of Helmholtz's experiments, it was essential to maintain the vibrations of a tuning-fork for a considerable time. He effected this by placing a short electro-magnet between the prongs of the fork, and affixing a platinum point at the end of one prong in such a manner, that, as the prong descended in its vibration, the platinum point dipped into a small cup of mercury that completed the circuit. When the prong receded, it was of course withdrawn from the mercury and the current was broken. As it is not possible for a tuning-fork to vibrate in more than one period, such an arrangement would evidently make and break the current as many times per second as the fork vibrated. When, therefore such an interruptor is inserted in the circuit with the click-rod on its resonant box, the latter must give out just such a sound as the fork is giving. With such a device, it is possible to reproduce, at almost any distance in a telegraphic circuit, a sound of a given pitch. It is therefore a true telephone.

REISS'S TELEPHONE.

The ease with which membranes are thrown into vibrations corresponding in period to that of the sounding body has already been alluded to on p. 80; and several attempts have been made, at different times, to make membranes available in telephony. The first of these attempts was made by Philip Reiss, of Friedrichsdorf, Germany, in 1861.

His apparatus consisted of a hollow box, with two apertures; one in front, in which was inserted a short tube for producing the sound in, and indicated by the arrow in the cut, Fig. 12; the other on the top. This was covered with the membrane *m*,— a piece of bladder stretched tight over it. Upon the middle of the membrane a thin piece of platinum was glued; and this piece of platinum was connected by a wire to a screw-cup from which another wire went to a battery.

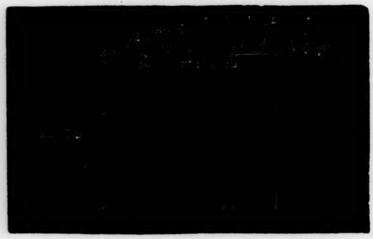


FIG. 12.

A platinum finger, S. rested upon the strip of platinum, but was made fast at one end to the screw-cup that connected with the other wire from the battery. Now, when a sound is made in the box, the membrane is made to vibrate powerfully; this makes the platinum strip to strike as often upon the platinum finger, and as often to bound away from it, thus making and breaking the current the same number of times per second. If, then, a person sings into this box while it is in circuit with the aforementioned click-rod and box, the latter will evidently change its pitch as often as it is changed by the voice. In this apparatus we have a telephone with which a melody may be reproduced at a distance with distinctness. But the sounds are not loud, and they have a tin-trumpet quality. If one reflects

upon the possibilities of such a mechanism, and upon the conditions necessary to produce a sound of any given quality, as that of the voice or of a musical instrument as described in preceding pages, he will understand that it can reproduce only pitch. It might here be inferred that something more than a single pitch is transmitted if the sound is like that of a tin trumpet, as stated; but the reason of this is that, whenever a current is passing between two surfaces that can move only slightly on each other, there is always an irregularity in the conduction, so as to produce a kind of scratching sound; and it is this, combined with the other, the true pitch, that gives the character to the sound of this instrument.

Dr. Wright found that a sound of considerable intensity could be obtained by passing the interrupted current through the primary wire of a small induction coil, and placing a conductor made of two sheets of silvered paper placed back to back in the secondary circuit. The silvered paper becomes rapidly charged and discharged, making a sound that can be heard over a large hall, and having the same pitch as the sending instrument.

COMPLAINANTS' EXHIBIT SECOND EXTRACT FROM DOLBEAR'S BOOK.

DOLBEAR ON THE SPEAKING TELEPHONE.

[Put in evidence by Complainants. Record, p. 439.]

The Telephone, by Prof. A. E. DOLBEAR. Boston: Lee & Shepard, 1877.

BELL'S TELEPHONE.

Professor A. Graham Bell, of Boston, independently discovered the same means for producing multiple effects over the same wire; but it appears he did not practically work it out as completely as did Mr. Gray. But while the latter was chiefly employed in perfecting the method as a telegraphic system, Professor Bell had set before himself the more difficult problem of transmitting speech. This he has actually accomplished, as we have so often been reminded during the past year.

Thoroughly conversant with the acoustic researches of Helmholtz, and keeping in mind the complex form of the air vibrations produced by the human voice, he attempted to make these vibrations produce corresponding pulsations in an electric current in the manner analogous to the electric interruptor.

Observing that membranes when properly stretched can vibrate to any kind of a sound, he sought to utilize them for this purpose. So did Reiss; but Reiss inserted the vibrating membrane into the circuit, and it was quite evident that such a plan would not answer, therefore the current must not be broken; but could an electric current be interfered with without breaking the connections?

The well-known reactions of magnets upon electrical currents, first noted by Oersted, and fully developed by Faraday, gave the clew to the solution. A piece of iron should be made to vibrate by means of sound vibrations, so as to affect an electro-magnet and induce corresponding electrical pulsations.

FIRST FORM OF SPEAKING TELEPHONE.

A membrane of goldbeater's skin was tightly stretched over the end of a speaking tube or funnel; on the middle of this membrane a piece of iron, N S, Fig. 13, was glued. In front of this piece of iron an electro-magnet M is so situated that its poles are opposite to it, but not quite touching it. One of the terminal wires of the electro-magnet goes to the battery B; the other goes to the receiving instrument R, which consists of a tubular electro-magnet, the coil being enclosed in a short tube of soft iron; the wire thence goes to the plate E′, which is sunk in the earth. On the top of R, at P, is a rather loose, thin disk of iron which acts as an armature to the electro-magnet below it.

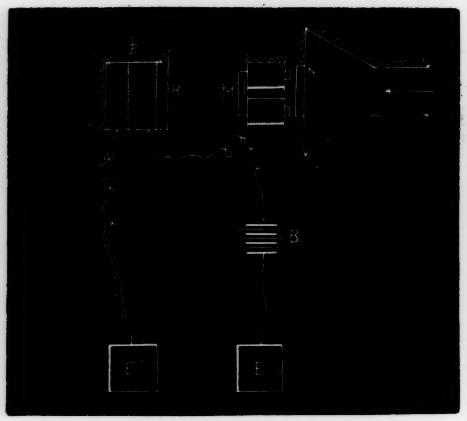


FIG. 13.

Supposing that all the parts are thus properly connected, the current of electricity from the battery makes both M and R magnetic; the electro-magnet M will inductively make the piece of iron N S a magnet, with its poles unlike those of the inducing electro-magnet; and the two will mutually attract each other. If now this piece of iron N S be made to move toward M, a current of electricity will be induced in the coils, which will traverse the whole circuit. This induced electricity will consist of a single wave or pulse, and its force will depend upon the velocity of the approach of N S to M. A like pulse of electricity will be induced in the coils when N S is made to move away from M; but this current will move through the circuit in the opposite direction, so that whether the pulsation goes from M to R, or from R to M, depends simply upon the direction of the motion of N S.

The electricity thus generated in the wire by such vibratory movements varies in strength proportional to the movement of the armature; therefore the line wire between two places will be filled with electrical pulsation exactly like the aërial pulsations in structure. Fig. 10, p. 98, may be used to illustrate the condition of the wire through which the currents pass. The dark part may represent the strongest part of the wave, while the lighter part would show the weaker part of the wave. The chief difference would be, that electricity travels so fast, that what is there represented as one wave in air with a length of two feet would, in an electric wave, be more than fifty miles long.

These induced electric currents are but very transient (see p. 31); and their effect upon the receiver R is to either increase or decrease the power of the magnet there, as they are in one direction or the other, and consequently to vary the attractive power exercised upon the iron plate armature.

Let a simple sound be now made in the tube, consisting of 256 vibrations per second; the membrane carrying the iron will vibrate as many times, and so many pulses of induced electricity will be *imposed* upon the constant current, which will each act upon the receiver, and cause so many vibrations of the armature upon it; and an ear held at P will hear the sound with the same pitch as that at the sending instrument. If two or more sound waves act simultaneously upon the membrane, its motions must correspond with such combined motions; that is, its motions will be the resultant of all the sound waves, and the corresponding pulsations in the current must reproduce at R the same effect. Now, when a person speaks in the tube, the membrane is thrown into vibrations more complex in structure than those just mentioned, differing only in number and intensity. The magnet will cause responses from even the minutest motion; and therefore an ear at R will hear what is said at the tube. This was the instrument exhibited at the Centennial Exposition at

Philadelphia, and concerning which Sir William Thomson said, on his return to England, "This is the greatest by far of all the marvels of the electric telegraph."

The popular impression has been concerning the telephone, that the *sound* was in some way conveyed over the wire. It will be obvious to every one who may read this, that such is very far from being the case. The fact is, it is a beautiful example of the convertibility of forces from one form to another. There is first the initial vibratory mechanical motion of the air, which is imparted to the membrane carrying the iron. This motion is converted into electricity in the coil of wire surrounding the electro-magnet, and at the receiving end is first effective as magnetism, which is again converted into vibratory motion of the iron armature, which motion is imparted to the air, and so becomes again a sound wave in air like the original one.

This was the first speaking telephone that was ever constructed, so far as the writer is aware, but it was not a practicable instrument. Many sounds were not reproduced at all, and, according to the report of the judges at the Philadelphia Exposition, ore needed to shout himself hoarse in order that he might be heard at all.

COMPLAINANTS' EXHIBIT DOLBEAR'S DESCRIPTION OF A MODIFIED REIS TRANSMITTER.

The Speaking Telephone, etc., by Geo. B. Prescott. Ed. of 1879, pp. 267–8.

[Record, page 429.]

The electrophone or modified Reis telephone (Fig. 126). In this instrument a ring of wood *a a* has a plate of iron *p* screwed to one side of it, the plate being in metallic connection with a screw cup leading to a battery. Upon the opposite side of the ring is a cross arm *b*, through which passes a screw *s*, carrying a point which may be adjusted at any required distance from the plate *p*. This screw *s* is also in metallic connection with the other terminal cup.

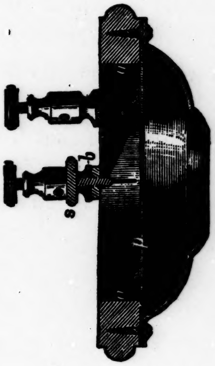


Fig. 126.

If a rather weak battery of two or three gravity cells be put in circuit with this, together with any form of receiving telephone, and the point be screwed down so as to touch the plate, and any kind of a sound be made in the cavity in front of the plate *p*, the circuit will be made and broken the number of times per second due to the pitch of that sound, and the like pitch will be given out by the receiving telephone; the loudness of this sound will depend upon the ability of the receiver to respond to the pulsations. The tones will be quite loud from a Morse sounder or from a relay.

If the point be drawn back so as not to touch the plate at all, and a drop of water be inserted between the point and the plate, and talking or singing be resumed, the articulation becomes remarkably good, though the sound is not very loud.

If a strong battery of fifty cells or more be put in circuit, and the screw be turned down, so as to have a jumping spark between the point and the plate, the vibrations of the latter introduce a variable resistance in the air. If, at the same time, there is a strong current, the result will be very loud talking. Indeed, it will be louder at the receiving than at the sending station. This has been used over the lines between Boston and New York and between Milford, N. H., and Boston. In each case every person in the room could hear the talking from the other end of the line. In this device it is found best not to use a very sharp point, but one having a surface like a sewing needle with about one eighth of an inch broken off from the point. Such a one gives much better results than a sharp point, for the obvious reason that a greater quantity of electricity can pass from such a surface than from a fine point.

If electricity of high tension like that from an ordinary electrical machine be used instead of the current from a battery, the result is the same; talking is possible; the articulation is good, but the tones are not so loud.

Sheet 1-2 Sheets.

C. F. Varley.

Telegraph.

No. 78,495. Patented Jun. 2, 1868.

Fig. 1.

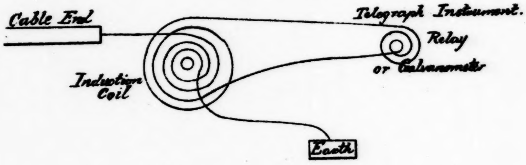


Fig. 2.

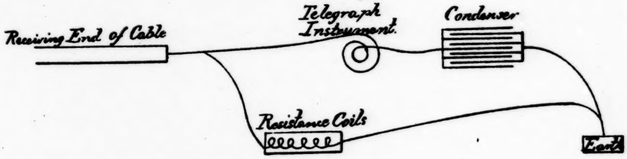


Fig. 3.

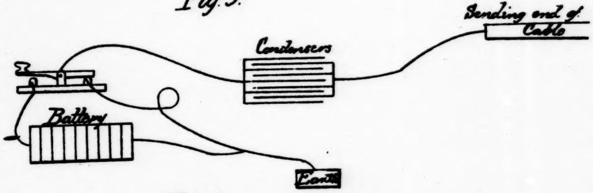
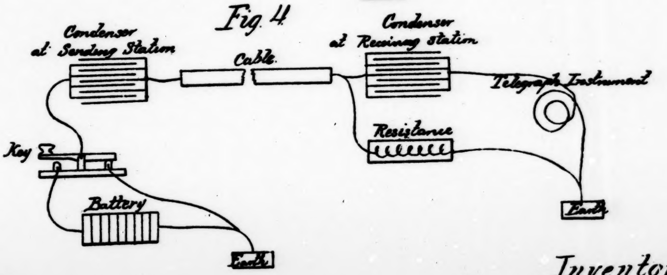


Fig. 4.



Witnesses.

C. A. Page Jr.

Inventor.
Cromwell Fleetwood Varley
by his attorney

Sheet 2-2 Sheets.

C. F. Varley.

Telegraph.

No. 78,495. Patented Jun. 2, 1868.

Fig. 5.

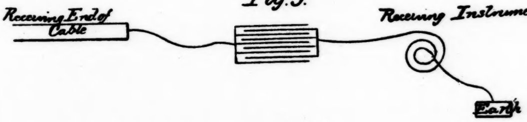


Fig. 1.

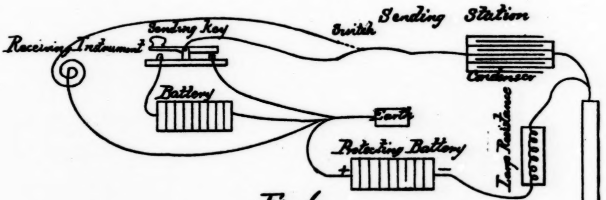


Fig. 6

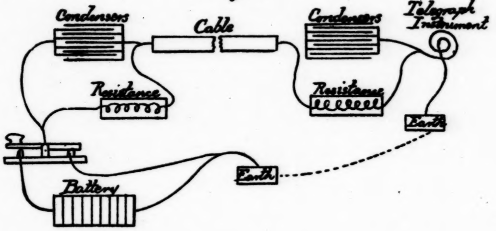
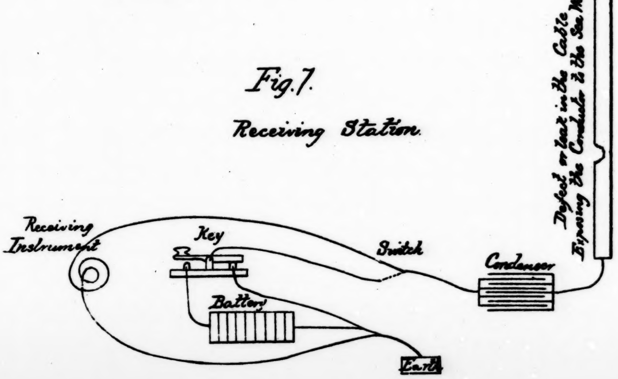


Fig. 7.

Receiving Station.


Cable
Defect or leak in the Cable
Exposing the Conductor to the Sea Water
Receiving Instrument
Key
Switch
Condenser
Battery
Earth

Witnesses

Inventor

Cromwell Fleetwood Varley
by his attorney

UNITED STATES PATENT OFFICE.

CROMWELL FLEETWOOD VARLEY, OF LONDON, ENGLAND.

IMPROVEMENT IN TELEGRAPHING.

Specification forming part of Letters Patent No. **78,495**, dated June 2, 1868.

To all whom it may concern:

Be it known that I, CROMWELL FLEETWOOD VARLEY, of London, England, temporarily residing in New York, county of New York, and State of New York, have invented certain new and useful Improvements in Electric Telegraphs; and I hereby declare the following to be a full, clear, and exact description of the same.

The objects of my invention are to cut off the disturbance arising from earth-currents, to obtain a high speed of signaling through long circuits, and, should the conductor become partially exposed, to preserve it from being eaten away by electrolytic action.

No means, prior to my invention, had been devised for effecting the first and third of these results. I have devised several other methods less perfect than those hereinafter described, but all embodying the general principle of my invention.

The invention consists of the arrangement of well-known apparatus, whose action, being of an electric and magnetic character, cannot be explained by drawings or models; but the accompanying diagrams and specification will enable those skilled in the art to understand the invention.

The telegraphic signals in this invention are made to depend upon the rate of change of electrical potential, and not upon the strength of the current or charge in the cable.

As the earth-currents—*i. e.*, the electric variations in the earth itself—change their strength slowly, the indications produced by them with this invention, in which the strength of the signals depends upon the rate of change of strength, are so feeble as to escape notice, and the embarrassment arising from this cause on long lines is, to all practical purposes, avoided.

There are two modes by which this is effected and a higher rate of signaling through long cables obtained. The first plan is by means of an induction-coil. The cable, at the receiving end of the circuit, is connected to the primary wire of an induction-coil, and through it to the earth. The secondary wire is connected to the telegraph-instrument. This arrangement is represented by Diagram No. 1.

Explanation of its action: On a current passing through the primary wire of the induction-coil, the iron core becomes magnetized, and this magnetization produces a current in the secondary wire, which acts upon the telegraphic instrument.

When the current in the primary wire has reached its maximum force, and is flowing steadily through, the iron core is magnetized to a certain fixed amount, and then the current in the secondary wire ceases. If, now, any change in the strength of the current through the primary wire occurs, the amount of magnetization of the iron core will vary, and a corresponding current in the secondary wire will result.

The earth-currents seldom pass from zero to their maximum and back again to zero (prior to changing sign) in less than five or six minutes, while the telegraphic signals are generally produced in a small fraction of a second.

With the former, although the currents are often very strong, the rate of change of strength is extended over several minutes, and consequently the current in the secondary wire is very feeble, as its strength is mainly dependent upon the rate of variation of the magnetism of the iron core.

The signaling currents or impulses are much more rapid or sudden, and consequently the variation of the magnetism of the iron core is much more sudden, and the currents generated thereby in the secondary wire are comparatively powerful and distinct.

Thus, then, suppose the earth to send a current through the line—say a positive (+) current from the sending to the receiving station—and to slowly magnetize the iron core, and, for ease of explanation, suppose this earth-current to remain for a time steady and uniform in strength; let, now, the sending-station make a signal. In doing so his battery adds its strength to or opposes the earth-current, accordingly as the signal sent is + or —, (positive or negative.)

This sharp and comparatively sudden addition to or subtraction from the earth-current produces a rapid augmentation or diminution of the magnetism in the iron core, and thus produces a distinct signal in the secondary wire.

For still further explanation, suppose the earth-current to be +, and to have a strength of 100 plus or positive, and the signal-current to have a strength of 10, if a positive signal be sent, the current will rapidly rise at the receiving end in the proportion of 100 to 110. This rapid increment of magnetism will produce a positive signal in the secondary wire, corresponding to the increment 10. But if a negative signal be sent, then the battery will be opposed to the earth-current, and the current will rapidly fall at the receiving end in the proportion of 100 to 90, the magnetism in the iron coil will experience a rapid decrease, and a negative signal will be produced in the secondary wire corresponding to the decrement (or negative increment) 10, although the current through the line or cable still remains strongly positive.

As the strength of those secondary signals is almost entirely dependent upon the rate of increment and decrement of the current through the primary wire, and as the slowest line yet constructed need not require so much as half a second to produce a clear signal, while the earth takes five minutes or six hundred half-seconds, the current arising in the secondary wire from the earth-current (which, although assumed to be ten times stronger, is six hundred times slower) is $\frac{10}{600} = \frac{1}{60}$ part only of the strength of the signal, and the effects of the earth-current are consequently practically cut off.

When signaling through a very long cable, a rapid succession of signals charges the cable and produces an electric wave, which is a long while subsiding, and acts at the receiving end in a somewhat analogous manner to the earth-current just described. This prevents signals from being transmitted in rapid succession by the ordinary means.

The above apparatus, which may be popularly described as disentangling the short high-crested waves from the large long swells, enables clear distinct signals to be produced rapidly one after the other.

The strength of the signals through the cable or telegraph-circuit is produced by the rate of the increments and decrements of current, and not by the current itself; and, as an imperfect illustration, if the great earth-current through the cable be compared with an Atlantic swell whose height is five fathoms, but spreading horizontally over five or six hundred fathoms, and whose sides will have an angle of, say, one hundred and seventy-eight degrees, and if the signals be compared with the ripples produced by the wind upon the back of the swell, and whose angles are each, say, sixty degrees, then an apparatus that will indicate these angles would scarcely notice the angle of one hundred and seventy-eight degrees, which is nearly a straight line, (or one hundred and eighty degrees,) while the small waves, with an angle each of sixty degrees, would be distinct, and such apparatus would disentangle the small signals from the big swell, paying almost no attention to the latter. Electric waves are entirely different from water waves; but the illustration may serve to explain the action of the former.

The second plan of effecting the above is more expensive in construction, but more perfect in action. A large condenser is inserted in the circuit at one or both ends, according to the circumstances of the case. At the receiving end of the line I prefer the following arrangement, (Diagram No. 2,) which gives a rapid rate of signaling.

The cable is connected to the one armature of the condenser through the telegraph receiving-instrument, and the other armature is connected with the earth. The cable is also connected to the earth by means of a resistance-coil, which is best when made of a long length of insulated copper wire wound round an iron core.

On a current running through the line or cable, it finds at the distant end two routes or channels, viz., the resistance-coil and the condenser. The condenser-route at the first moment offers no other sensible resistance than that of the receiving-instrument, while the other, owing to the magnetic inertia of the iron core, offers at the first moment a considerable resistance. The condenser is rapidly charged, and, as soon as it is charged to the full force or potential of the current in the cable, all the rest of the electric current goes through the resistance-coil to earth, and no more current is shown upon the receiving-instrument. If, now, the potential in the cable be reduced or increased a little, the charge in the condenser is reduced or increased in proportion, and a negative or positive signal can be distinctly produced at pleasure, although the electric current or charge in the line or cable has not changed sign, but only varied in strength. The resistance-coil between the cable and the earth may be dispensed with; but then the little signal-wave does not reach its maximum so rapidly, and consequently the signals are not so rapid. (*Vide* Diagram 6.)

Observe, the receiving-instrument may be placed between the second armature of the condenser and the earth or ground, instead of between the cable and the first armature. A condenser may also be employed at the sending end of the line or cable, either with or without a condenser at the receiving end of the line or cable. When a condenser is inserted at the sending end only of the line, the resulting signal is very similar to that produced by a condenser at the receiving end only; but the disturbing action of the earth-current, however, is more felt when the condenser is only placed at the sending end, because the earth-current has to charge the cable in addition to the condenser, all of which charging-current has to pass through the receiving-instrument. When the condenser is used at the sending end of the cable or line (Diagram 3,) the cable is connected to the one armature of the condenser and the telegraph-key to the other armature of the condenser. An ordinary double or reversing key is generally used, so that when the one is depressed a positive charge is communicated to the condenser-armature attached to it, and when the other is depressed a negative charge is communicated to it.

If the key had been connected to the line or cable in the usual manner, a constant or permanent current would have been produced through the cable so long as the contact was maintained, and this current would only begin to die away when the contact with the battery was broken or reversed. But when the condenser is interposed in the circuit, as described, so soon as the current from the battery has charged the condenser the current from the condenser is arrested, and variations in the length of the battery-contact beyond a fixed amount will produce no change in the amount of current thrown into or induced in the cable. In this way great uniformity and regularity of signals are obtained.

At the sending end of the line it is sometimes advisable to use a smaller condenser than at the receiving end, and higher battery-power, because the more sharp and sudden the impulse is given the quicker will the signal appear at the distant end.

If the dimensions of the condenser be reduced—say halved—and the battery-power be augmented in the inverse ratio, then the shock or impulse will be the same in amount, but more sudden, producing a rather more rapid signal at the distant end; but the disturbing action of the earth-currents is reduced as the dimensions of the condenser are reduced at the receiving end.

In some cases—such, for example, as where the Morse instrument is used—it is advisable to connect together the two armatures by means of a very large resistance, as shown in Diagram 6, so that after the condenser is charged the current through the cable shall not entirely cease. Thus the sharp, sudden impulse of the condenser charges the cable, and would produce a dot, but not a line or dash. The weak current through the large resistance, however, maintains the current in the cable, and a dash is produced, the Morse armature being held down by this weak current so long as the key is held down.

On the key being elevated, the charged condenser is connected to the ground, if the condenser be at the sending end; and in discharging itself the condenser produces a short, sharp current in the cable in the opposite direction, which rapidly terminates the signal at the distant end of the cable.

All cables are liable to have their insulation impaired. When this is the case, and the copper conductor is exposed to the sea-water, the copper is decomposed whenever a positive current is permitted to flow from the copper into the water, forming chloride of copper, which is soluble, and diffuses itself and floats away.

If the cable be kept always negative to the water, the action of the positive current flowing into the wire from the water is to preserve the wire from decomposition. To effect this I place a condenser at each end of the cable, (Diagram 7,) and also connect to the cable, through a large resistance (or long coil of fine wire,) a battery whose positive pole is connected to the earth and negative pole to the resistance-coil. This keeps the cable always negative to the water, and yet the signals through it and the condensers are either positive or negative, at pleasure. Suppose the signal-impulse to be a positive one, it weakens the negative character of the charge in the cable and also in the distant condenser, and immediately a corresponding positive signal is produced in the distant instrument.

If the signal-impulse be negative, it increases the negative charge in the cable and also in the distant condenser, and therefore produces a negative signal in the distant instrument, and thus, although positive and negative impulses are produced at the distant end, the cable has been only less or more negative, but never positive, to the sea, and therefore, the conductor has been constantly under the preservative action of the negative current. Thus, then, the action of the condensers and battery has been not only to cut off the effect of the earth-currents and to expedite the transmission of signals, but also to preserve the conductor of the cable from destruction, if exposed to the sea-water.

In Diagram 7 the place of the switches or commutators is shown. These have been omitted in the other diagrams to simplify them. These commutators are of the ordinary well-known form common to most systems of submarine telegraphing, and are not a part of this invention.

Having now described my invention, and the manner in which the same is or may be carried into effect, what I claim, and desire to secure by Letters Patent, is—

1. In so arranging telegraphic apparatus as to work by the variation of the increment and decrement of electric potential, and not by the direct action of the electric current itself, as and for the purposes set forth.

2. The use of an induction-coil at the receiving end of the cable, one of its wires being connected between the cable and the ground, and the other or secondary wire connected with the receiving-instrument, as and for the purposes set forth.

3. The use of a condenser or condensers between the receiving end of the cable and the earth, with or without resistance-coils between the cable and the earth, as and for the purposes set forth.

4. The use of a condenser at the sending

end of the cable, with or without resistance-coils connecting its two armatures, as and for the purposes set forth.

5. The use of a condenser at each end of the cable, the cable being connected with the ground through a resistance-coil and a battery, so as to keep the cable always negatively electrified, as and for the purposes set forth.

In testimony whereof I have signed my name to this specification before two subscribing witnesses.

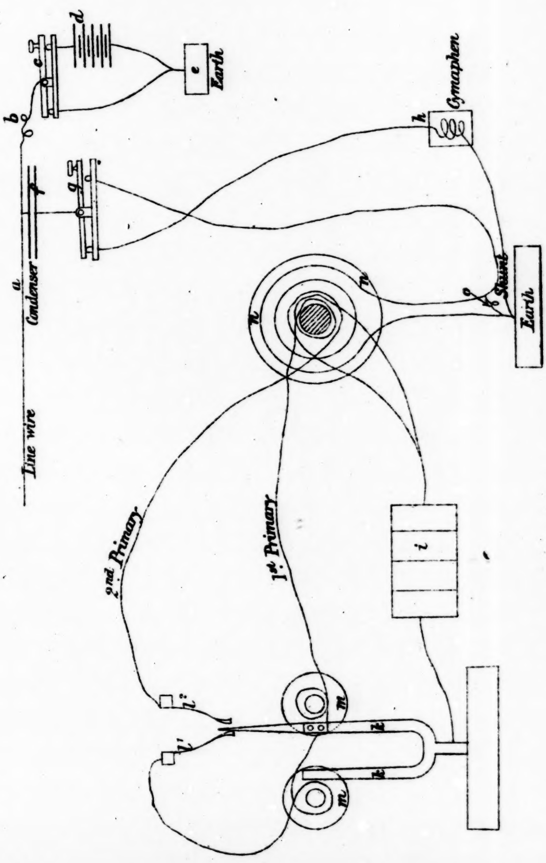
C. F. VARLEY.

Witnesses:
W. BAILEY,
C. G. PAGE, Jr.

A.D. 1870. April 8. N.º 1044.
VARLEY'S SPECIFICATION.

SHEET. 1.
4 SHEETS.

FIG. I.



A.D. 1870, April 8, No 1044.
VARLEY'S SPECIFICATION.

SHEET 2
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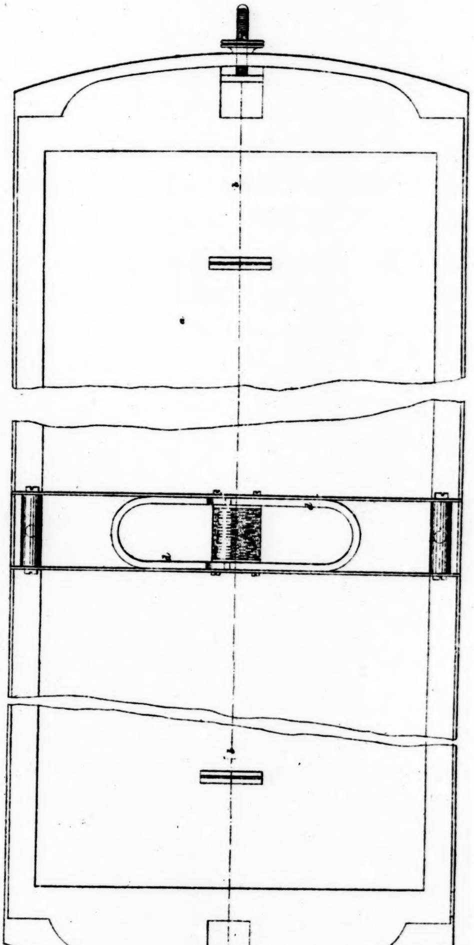


FIG. 2.

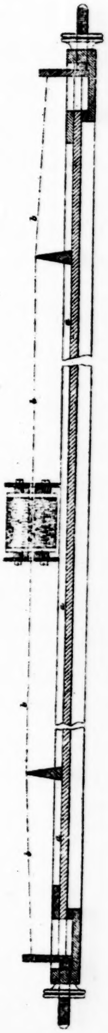


FIG. 3.

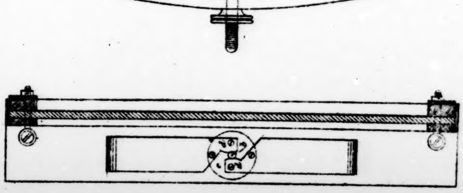


FIG. 4.

A.D. 1870. April 8. N°. 1044.
VARLEY'S SPECIFICATION.

SHEET 3.
4 SHEETS.

FIG. 5.

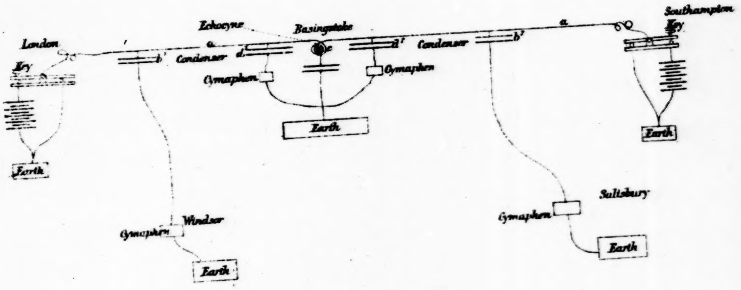
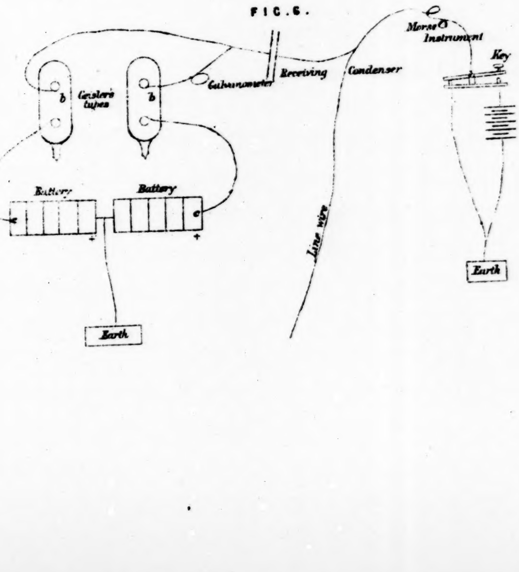


FIG. 6.



SHEET 4.
4 SHEETS.

A.D. 1870. APRIL 8. N° 1044.
VARLEY'S SPECIFICATION.

FIG. 7.

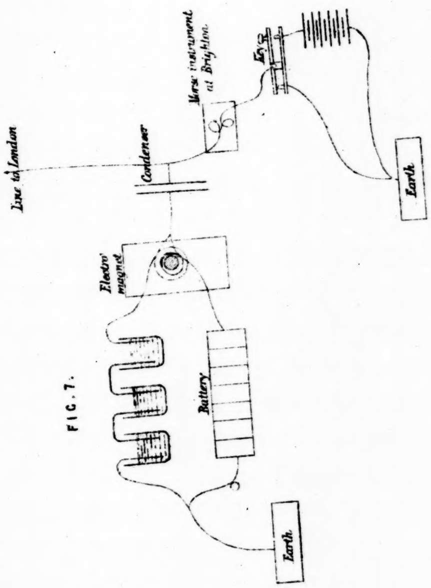
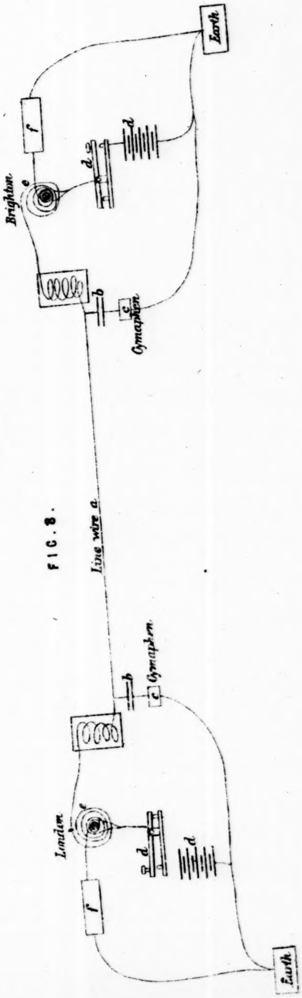


FIG. 8.



A.D. 1870, 8th April N° 1044.

Electric Telegraphs.

LETTERS PATENT to Cromwell Fleetwood Varley, of Beckenham, in the County of Kent, for the Invention of "IMPROVEMENTS IN ELECTRIC TELEGRAPHS."

PROVISIONAL SPECIFICATION left by the said Cromwell Fleetwood Varley at the Office of the Commissioners of Patents on the 8th April 1870.

CROMWELL FLEETWOOD VARLEY, of Beckenham, in the County of Kent. "IMPROVEMENTS IN ELECTRIC TELEGRAPHS."

This Invention has for its object the increase of the transmitting power of telegraph circuits by enabling more than one operator to signal independent messuages at the same time upon one and the same wire to and from independent stations.

In working land lines it is usual to produce the signals by means of the passage of a current of electricity producing magnetic action, as in the Morse or Hughes instruments, or chemical action, as in the Baines machines.

By my Invention I superpose upon the currents used for working the ordinary telegraphs rapid undulations or waves which do not practically alter the mechanical or chemical power of the ordinary signal currents, and by new apparatus hereinafter described these undulations are made to produce distinct and independent audible or other signals so long as these undulations are produced, whether ordinary signal currents be flowing or not.

As a rough mechanical illustration of the way in which I propose to pass two sets of electric signals simultaneously and in either direction through the same line wire without interference I will suppose a rope stretched over two distant pulleys by means of weights at each end; if the near weight be raised the distant one falls. In this way signals are transmitted by the connecting rope, which may be called current signals; if now two small pulleys capable of rising and falling rest upon the rope between but near to the supports they will simply rotate when the rope is shifted backwards and forwards; if now an operator at one end strike the rope vibrations or waves will be produced which will cause the other small pulley to dance or make vibration signals. Consequently the operator who shifts and the operator who strikes the rope can each produce independent signals on one and the same rope.

Suppose the rope to travel over several fixed pulleys the operation of shifting the rope will produce distinct current signals from end to end of the line as before, but between each fixed pulley vibrations can be produced, and so a number of intermediate stations can communicate independently of each other and independently of the current signals through the line.

With this mechanical simile the following will be more easily understood.

The way in which I carry my electric Invention into operation is as follows:—

An electro-magnet offers at the first moment great opposition to the passage of a current of electricity, and therefore it may be considered as partially opaque to the transmission of very rapid alternations or electric waves.

I attach to the line at desirable parts condensers. In the first instance I will assume only two condensers, one at each end, attached near each end of an ordinary telegraph line.

The first or communicating station produces in its condenser rapid charges and discharges; these add to and take from the line a number of small electric impulses without affecting the mean magnetizing power of the currents through the line. These impulses charge and discharge the second condenser at the other end.

These undulations in the second condenser can be utilized in the following manner:—

1. If the condenser be made of paper and metal foil the rapid charges and discharges produce a musical sound.

2. If those rapid alternations be made to pass round a helix containing an iron rod a musical sound is produced.

3. If these currents pass round a helix containing a magnetized harmonium tongue the currents make it vibrate audibly if the currents be properly timed, and the effect is increased if a feeble current of air be passing the tongue. By adding tubes of proper length and sounding boards and other appliances for communicating vibrations the power of the signal is increased.

4. By placing the magnetized tongue of a musical comb between the poles of an electro magnet with only a small iron core, or inside a coil, it is made to vibrate whenever these undulations are passing.

Another method of producing sound from the undulations consists of stretching a music wire through hollow trelices; the currents magnetize and demagnetize the tone, this wire being also placed between the poles of permanent magnets.

Harmonious currents cause this wire to vibrate. In some cases it may be useful to employ inharmonious currents to stop or silence the vibrations.

The two latter methods will only speak when vibrations or harmony with the tongue are made to pass, and consequently in some cases two or more distinct sets of vibrations can be made to act on two or more sets of apparatus differently tuned, and to permit of several distinct communications to be transmitted simultaneously upon the same section of a single line wire.

By introducing between the receiving condenser and a Morse or other ordinary receiving instrument a current reverser keeping time with the vibrations, these alternating currents are made to flow through the receiving instrument in one direction, and are then competent to work the Morse or other ordinary receiving instrument.

6. When it is desirable to subdivide the vibrating sections of a line an electro-magnet, or, what is better, two electro magnets are inserted in the circuit, and a condenser may with advantage be placed between the circuit and the earth connecting the condenser with the circuit between the two electro magnets.

In this way, without interfering materially with the ordinary signals through the line, the vibrating sections are separated from each other by withdrawing the iron cores from the electro magnets, or short circuiting the electro magnets the vibrations are passed through to the next station.

7. Another method consists of inserting a reflecting galvanometer between the condenser and the earth (or between the line and the condenser); the vibratory or secondary signals can be read off by observing its vibrations.

8. Vibrations are rendered sensible by placing a moveable iron bar between the poles of an electro magnet or inside a helix, and one or both of its ends between the poles of permanent magnets; the latter are covered with brass or any non magnetic matter; the vibration currents cause it to vibrate between the poles of the electro or permanent magnets, and so produce distinctly audible sounds.

9. There are other methods of utilizing these superposed vibrations, such as connecting to the condenser an electrometer like that of Milner or Pettier. An intermediate Morse or other such line instrument would cut off the vibration signals or reduce them much; this opposition of the intermediate electro magnet may be cut off by connecting the terminals of a condenser to the circuit on each side of the magnet.

There are several methods of producing these vibrations in the wire:—

1st. If a tuning fork be placed between the poles of an electro magnet with a spring contact so arranged that when at rest the battery current flows through the electro magnet the latter will attract the tuning fork and break the circuit; the magnetism then ceases, and the tuning fork springs back and renews the circuit; in this way it keeps vibrating so long as the battery is in action.

A secondary wire around this magnet produces currents in opposite directions, and by placing this secondary wire in circuit with the line wire the necessary vibrations are produced.

2nd. The secondary wire may be connected between the earth and the condenser attached to the line wire; this method does not add to the resistance of the main circuit, and is therefore preferable.

3rd. A tongue similar to those used in harmoniums is made to vibrate by air between contact points, and so connect the condenser alternately with the battery and the ground, and so produce the alternations, or it may be made to connect the condenser alternately to the + or — pole of a battery whose opposite poles are connected to the earth.

4th. A magneto machine rapidly rotating will do the above duty equally well if its speed of rotation be controlled by a good governor.

The tuning fork and vibrating tongue arrangement can be set to and can keep up any desirable rate of vibrations.

The ordinary telegraph keys and switches are used for connecting the various parts of the apparatus together.

In constructing the dry paper condensers it is best to dip the paper in varnish and attach metal leaf (such as gold, silver, or copper) to the paper, and lay these metal coated papers between metal foil.

The double speaking apparatus of Dr. Gintl, or of Firschen, can be used on lines working with the above described vibrations.

When these are used I prefer inserting a hollow helix between the double speaker and the line, and by inserting iron rods in this helix the difficulty arising from the inductive capacity of the line is almost wholly removed. This is a new improvement, and will render these apparatus actually useful instruments.

SPECIFICATION in pursuance of the conditions of the Letters Patent filed by the said Cromwell Fleetwood Varley in the Great Seal Patent Office on the 8th October 1870.

CROMWELL FLEETWOOD VARLEY, of Beckenham, in the County of Kent. "IMPROVEMENTS IN ELECTRIC TELEGRAPHS."

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In working land lines it is usual to produce the signals by means of the passage of a current of electricity producing magnetic action, as in the Morse or Hughes instruments, or chemical action, as in the Baines machines.

By my Invention I superpose upon the currents used for working the ordinary telegraphs rapid undulations or waves which do not practically alter the mechanical or chemical power of the ordinary signal currents, and by new apparatus hereinafter described these undulations are made to produce distinct and independent audible or other signals so long as these undulations are produced, whether ordinary signal currents be flowing or not.

As a rough mechanical illustration of the way in which I propose to pass two sets of electric signals simultaneously and in either direction through the same line wire without interference, I will suppose a rope stretched over two distinct pulleys by means of weights at each end. With such an apparatus, if the near weight be raised the distant one falls, and in this way signals may be transmitted by the connecting rope, which may be called current signals. If now two small pullies capable of rising and falling rest upon the rope between but near to the supports they will simply rotate when the rope is shifted backwards and forwards; but if now an operator at one end strike the rope vibrations or waves will be produced, and will cause the small pulley at the other end to dance, and so vibration signals may be given. Consequently the operator who shifts and the operator who strikes the rope can each produce independent signals on one and the same communicating cord. Suppose the rope to travel over several fixed pulleys the operation of shifting the rope will produce distinct current signals from end to end of the line as before, but between each fixed pulley and the next to it vibrations can be produced, and so a number of intermediate stations can communicate independently of each other, and independently of the current signals through the line.

With this mechanical simile the following will be more easily understood.

The way in which I carry my electric Invention into operation is as follows:—

Condensers are attached to the line at the places where the wave signals are to be communicated and received. In the first place let us assume only two condensers, one at each end, attached near each end of an ordinary Morse telegraph circuit. The first or communicating station to make a signal produces in its condenser rapid charges and discharges by means described; further on these add to and take from the line a number of small electric impulses without affecting the mean magnetizing power of the ordinary Morse currents through the line These impulses charge and discharge the second condenser at the other end, and this condenser is coupled with a receiving instrument which is sensitive to these undulations and renders them apparent by sound or otherwise.

Figure 1 is a diagram of the instruments at one of the stations of such a line; *a* is the line wire, I will suppose it to be an ordinary land line wire 50 miles long and suspended in the usual way; *b* is the Morse instrument, *c* the sending key for the Morse signals, *d* the battery in connection with this key, and *e* its earth connection; *f* is a condenser of about 3 micro farads, one armature of which I couple with the line wire and the other with a key *g*, which when not depressed puts the condenser in communication with the wave signal receiving instrument *h*, which I call a "cymaphen;" this instrument is shown at Figures 2, 3, and 4. The key *g* when depressed for sending a wave signal puts the condenser in connection with the apparatus by which such waves are generated; this apparatus consists of a battery *i*; ten quart cells of Daniel's battery will be suitable.

One pole of the battery *i* is connected with the tuning fork *k*; this fork may conveniently be of such dimensions as to make 200 vibrations in a second. l^1, l^2, are two platina pointed contact making springs, capable of fine adjustment by means of screws. The spring l^1 when the fork is at rest is in metallic contact with it or with a metal arm attached to it, and the spring l^2 is removed just out of contact. The current from the battery *i* then passes in the coils of the electro magnet *m*, the poles of which have between them the two horns of the tuning fork. The coils of this magnet may be about 3½ inches long, and 1½ inches diameter, and of No. 16 (B.W.G.) silk covered copper wire. When the current is flowing through the coils of the electro magnet the horns of the fork *k* are drawn apart and the spring l^1 loses its contact; then as the attraction of the magnet ceases the horns of the fork spring back; this re-makes the contact, and so a continual tremor is communicated to the tuning fork. In the same circuit with the electro-magnet there is at *n* a primary coil wound upon a bundle of iron wires as a core, and on the same core but wound in the opposite direction is a second primary coil which is in connection with the spring l^2, so that currents pass alternately in the two primary coils, and at each alternation the polarity of the core is reversed. On the core there is also another or secondary coil, in which currents are induced by the changes of polarity of the iron core. One end of this secondary coil is connected with the earth, and the other when a wave signal is to be sent is by the key *g* put in connection with the condenser *f*, and produces in it rapid charges and discharges.

The core may conveniently consist of a bundle of thin soft iron wires, 1 inch in diameter and 32 inches long. On the centre of the bundle is wound for a length of eight, the first primary coil consisting of four layers of No. 16 silk covered copper wire. Over this is wound the second primary coil, consisting also of four layers, and outside this again is wound the secondary coil consisting of eight layers of No. 24 silk covered wire. The ends of the bundle composing the core are folded over so as completely to enclose the coils.

A small resistance coil *o*, or a condenser of about two micro farads, is placed between the poles of the secondary coil to take off the violence of the shock, so that the operator shall not be inconvenienced. The wave signal receiving instrument *h* is shown in plan at Figure 2, in longitudinal section at Figure 3, and in transverse section at Figure 4. It consists of an iron frame containing a sounding board *a* over bridges, at the ends of which a hard drawn iron or steel wire *b* is stretched from one end to the other; this wire is about four feet and six inches long between the bridges; it is of No. 14 gauge, and is strained so as to sound the same note as the tuning fork of the sending instrument. This wire passes through a hollow helix *c*, three inches in length, ⅙ of an inch internal diameter and 1½ inches external diameter. The helix is wound with No. 35 B.W.G. copper wire insulated with silk. This coil is attached to the frame supporting the sounding board, but does not touch the latter. Two horse shoe magnets *d* are placed one on each side of the wire. The currents magnetize the wire inside the helix, and so cause it to be attracted and repelled from one magnet to the other. When the wire is properly tuned so as to vibrate synchronously with the apparatus at the distant end making the alternations in the current the sound from very feeble currents is distinctly audible. A piece of felt or leather resting against the wire is sometimes used to "damp" the wire and stop its vibrations as soon as the impulses cease.

A small piece of metal similar in dimensions to a gold five franc piece may be made to rest by a spring lightly against the sounding board somewhere near its centre. When the vibrations of the latter are powerful enough to make this piece of metal dance, the sound is increased in power four or five times by this little disc or sound reinforcer, or the sound may be augmented by clipping on to the wire near the helix a disc of about the size of a penny piece of thin sheet metal; this causes the vibration of the wire to produce a greater disturbance in the air than it otherwise would, and a louder sound is perceived.

By attaching a stethescope to the sounding board for the reader to rest his ear against very feeble sounds are rendered sufficiently audible; I prefer to use a Scott Allison's stethescope.

The sounding board may be replaced by a a strained diaphragm or drum-head, on which one of the bridges over which the wire is strained is supported; this arrangement gives a better sound with very feeble currents, but with moderate currents the sounding board appears to have the advantage.

Two sets of wave signals may be transmitted and received simultaneously through the same wire, and independently of the current signals if a sufficient difference be made in the periods of the two sets of waves. Thus, if waves of 200 vibrations in the second, and waves 850 or 900 vibrations in the second, be simultaneously transmitted and received by two separate cymaphens, the one adjusted to the slow, and the other to the rapid vibrations, they may be separately read, as the vibrations which affect the one are inoperative on the other. This arrangement is not applicable when working long distances, as the rapid waves would in a long distance be lost.

Figure 5 is a diagram illustrating the arrangements I make when the wave signals are used to communicate between intermediate or branch stations without interfering with the working by ordinary instruments of the main line; *a* is the line wire, say between London and Southampton, and through it it is desired that the intermediate station, Basingstoke, shall without interference with the through messages be able to communicate to and fro with the branch stations, Windsor and Salisbury. At these branch stations I provide wave signal apparatus such as already described in respect to Figure 1, coupled with condensers b^1, b^2, at the places where the branches run into the main line. At the intermediate station, Basingstoke, I divide the line wire into two sections (as far as the wave signals are concerned) by introducing at *c* an instrument which is opaque to these waves, whilst it allows the ordinary long current signals to pass freely. This opaque instrument *c* I call "echocyme," and on either side of it I connect with the line wire a condenser d^1, d^2, and wave signalling apparatus, as already described.

An electro magnet offers at the first moment great opposition to the passage of a current of electricity, and may be considered as nearly opaque to the transmission of very rapid alternations of current or electric waves. The "echocyme" may consequently be a simple electro magnet, or what is better is to wrap an induction coil with two wires so as to form one continuous coil; this is put into the line circuit. The junction between these coils is connected to the one armature of the condenser, whose other armature is connected to the earth. The momentary action of a current on passing through one wire charges the condenser. The secondary action upon the other wire checks the current that the condenser would have sent on through the other wire on to the remainder of the main line circuit; by varying the size of the condenser according to the nature of the line and currents employed a nearly absolute stopper of the vibrations signals is produced.

The coil which I have used for this purpose has the following dimensions: iron bundle one inch in diameter, length of coil 8 inches, and wound with No. 26 insulated copper wire to a diameter of 2 inches. The condenser connected between the echocyme and the earth in the case which I have taken for illustration should be of about $\frac{1}{10}$ of a microfarad. At the termini Morse or other ordinary instruments may be used.

There are various ways in which the wave signal receiving apparatus may be constructed, although that which I have already described I prefer.

Thus the condenser itself may be the receiving instrument. If the condenser be made in the following manner the rapid charges and discharges will produce a musical sound. Sheets of tinfoil (for example, one foot square) are separated by one or more sheets of thin dry paper; the 1st, 3rd, 5th, &c. sheets are joined together; the 2nd, 4th, 6th, &c. also join together. The odd numbered sheets are connected to a binding screw or terminal, and the even numbered sheets to another terminal. Such a condenser consisting of from 20 to 50 sheets will be found to be much agitated and to produce a loud note with 500 alternations of current per second if the potential be 50 to 100 votts.

In constructing the dry paper condensers the following method seems to answer best:—Very thin uniform paper is dipped in shellac varnish coated on one side with gold leaf and then dried. The non gilt surfaces of 2 sheets of paper are put together so as to leave the gilt surfaces outside; the tinfoil plates are placed outside of these and built up in the usual manner, connecting the 1st, 3rd, 5th, 7th, &c., plates to one armature of the condenser, the 2nd, 4th, 6th, 8th, &c., being joined to the other armature of the condenser. If the rapid alternations of current be made to pass round a helix containing an iron rod, the iron rod will issue a feeble but distinct sound. The rod used may be $^1/_8$th of an inch in thickness, 18 inches in length, and covered to a diameter of one inch with No. 35 insulated copper wire. This arrangement requires strong currents. If the currents pass round a flat coil in which a magnetized harmonium tongue is placed, the currents will act upon it like the needle of a galvanometer and cause it to vibrate.

The sound is increased by causing a feeble current of air to pass the tongue.

If a steel tongue, similar to one of those used in a musical box, be magnetized and placed inside a helix of fine wire, and its lip is placed between the poles of a powerful permanent magnet, the alternating currents will cause the tongue to vibrate and produce a musical sound so long as the alternations are operating.

By coating a wire, strained, as is shown in Figures 2 and 3, near the coil, with a short tube of gold or platinum, and letting a light spring formed of the same metals rest against the wire, a relay is produced, which bringing into operation a local battery can be used to increase the sound or to relay on the signals to another line.

A thick music wire, much thicker than those used in pianofortes, is found to give the best results for sound. A thin wire is thrown into greater oscillation than a thick one, and admits of being utilized for visible signals in the following way:—

A steel wire of about No. 40 gauge is stretched through the helix in front of a very narrow slit. A flame is passed behind the slit, but the light coming through is checked by the wire; the moment, however, the wire is put into vibration light passes, a lens is placed in front, and by it a magnified image of the luminous slit is projected upon a white screen so long as the wire vibrates.

Vibration are rendered sensible by placing a moveable iron bar between the poles of an electro magnet or inside a helix, and one or both of its ends between the poles of permanent magnets; the latter are covered with brass or any non magnetic matter. The vibration currents cause it to vibrate between the poles of the electro or permanent magnets, and so produce distinctly audible sounds. Another method of utilizing these alternations is by introducing between the receiving condenser and a Morse or other ordinary receiving instrument a current reverser keeping time with the vibrations; these alternating currents may be made to flow through the receiving instrument in one direction, and are then competent to work the Morse or other ordinary receiving instrument. Or a similar result may be obtained by the arrangement shown at Figure 6, which consists in connecting the receiving condenser to two "Geisler's" vacuum tubes *a* and *b*; the latter are connected with voltaic batteries C, Z, consisting of a large number of elements. The one tube *a* is connected to the "positive pole" of a battery whose "negative pole" is connected to the earth. The second tube *b* is connected to the "negative pole" of a battery whose "positive pole" is to earth. These batteries must have nearly power enough to make a current pass through the tubes; for example, supposing three hundred cells of a battery be able to leap across the exhausted tube 290 should be used with each tube. When a positive current arrives it will help the battery whose positive pole is connected to the earth and cause a current to pass through its tube *b*. The next instant the current is reversed; this causes a current to pass through the other tube *a*; in this way an electric valve is produced separating the positive from the negative currents, and producing a rapidly intermittent current in one direction only. If a reflecting galvanometer be enclosed in the circuit formed by the batteries and the tubes the wave signals will be indicated by it.

Another method of producing an electric valve for separating the positive from the negative currents is illustrated by Figure 7, and consists in connecting, say, 5 cells of Daniel's battery with 3 cups containing dilute sulphuric acid with platinum plates joined up so as to form 3 decomposition cells in series. Between the battery and the 3 cups is inserted the galvanometer or other instrument that is to be worked; the junction between the instrument and the cups or decomposition cells is connected to the condenser. The other junction between the battery and the decomposition cells is connected to the earth. The first action of the battery is to polarize the platinum plates when the current almost entirely ceases, the three pairs of polarized platinum plates balancing the 5 Daniell's cells. The moment a current arrives from the condenser it finds two channels open to the earth,—the one the battery, the other the decomposition cells. Suppose the positive pole of the battery to be in connection with the earth and a positive current arriving from the condenser, at first it divides itself, part going through the battery, part through the decomposition cells. The action of the current upon the latter is to depolarize them, and they then immediately resist its flow.

The next moment a negative current flows from the condenser; this negative current is assisted by the partly depolarized plates, and the battery and the former become repolarized. It is best to wrap the instrument, as the diagram shows, with two wires connecting the one with the cups, the other wire with the battery, and their junction with the condenser.

The result is that whether it be a negative or positive current that is sent into this arrangement the action upon the instrument is the same, and thus out of alternating currents a continuous action is produced.

The platinum plates for this purpose must be very small and very close together, to reduce as much as possible their inductive capacity and resistance.

Another method consists of inserting a reflecting galvanometer between the condenser and the earth (or between the line and the condenser); the vibratory or secondary signals can be read off by observing its tremor. The mirror of this galvanometer must be deadened by water or other damper, and it is best to produce the signals by interrupting the vibrations instead of the reverse. The vibrations keep the mirror oscillating, the image becomes spread out, and the light enfeebled. The moment the vibrations are cut off the light contracts. The effect is the "spread out" light is feeble, the "concentrated" is bright, and thus the signals can be flashed by long and short duration like the Morse alphabet.

Another method of utilizing these superposed vibrations is to connect to the condenser an electrometer like that of Milner or Pettier. A resistance coil of about 1,000 ohms is connected between the condenser and the earth as a shunt to the electrometer to prevent the Morse signals from affecting it to any sensible extent; or the wave signals may be read by the sense of touch. For this purpose I use a handle made of hard charcoal, and divided into two parts longitudinally. The parts are separated by a sheet of gutta percha, and are connected the one with the armature of the condenser, the other with the earth. The handle being moistened and covered with a rag wetted with weak salt and water is firmly grasped in the hand.

An intermediate Morse or other such line instrument would cut off the vibration signals or reduce them too much; this opposition or opacity of the intermediate instrument is destroyed by connecting the terminals of a condenser to the circuit on each side of the magnet. Thus, if I wish wave signals to pass a Morse instrument I couple the armatures of a condenser of 3 to 10 microfarads with the line wire, one on either side of the Morse instrument. The working of the Morse line, if there are many instruments in circuit, is also in this way improved.

There are several methods of producing electric waves in the lines in addition to that already described.

A tongue similar to those used in harmoniums is made to vibrate by air between contact points, and so connect the condenser alternately with the battery and the ground, and so produce the alternations, or it may be made to connect the condenser alternately to the + or − pole of a battery whose opposite poles are connected to the earth.

A magneto machine rapidly rotating will do the above duty equally well if its speed of rotation be controlled by a good governor.

The double speaking apparatus of Dr. Gintl, or of Frischen, can be used on lines working with the above described vibrations.

Figure 8 is a diagram of this arrangement. *a* is the line wire; *b*, *b*, the condensors; *c*, *c*, the cymaphens, wave signal transmitters, and parts connected therewith; *d*, *d*, are the current signal keys and batteries; and *e*, *e*, are the magnets of Dr. Gintl or Frischen's receiving instruments; and *f*, *f*, are their resistance coils. I prefer wrapping the magnets *e*, *e*, with three or four wires, using one wire between the key and the earth through its resistance coil, and the two or three wires joined into one circuit attached to the line wire. I insert a hollow helix between the double speaker and the line, and by putting iron rods in this helix the difficulty arising from the inductive capacity of the line is almost wholly removed; this is a new improvement and will render these apparatus actually useful instruments. The helix may conveniently be of No. 26 silk covered wire and 10 inches long, with a diameter inside of $1^1/_2$ inches, and outside of 4 inches; small iron rods are placed in this helix one by one until it is found that the finger key does not affect the indicator of the home receiving instrument. By using these instruments, these apparatus together with cymaphens, as is shewn in Figure 8, three messages can be sent from end to end of such a circuit at the same time independently of each other; for this purpose the cymaphen key must have a spring contact so that the circuit between the condenser and the earth is never broken until the contact with the secondary coil is complete.

I would remark that in electric telegraphs the use of sound signals is not claimed by me and is not new; for example, in working step by step instruments in which a pointer should indicate the desired letter on a dial it has been common when the instrument is out of order and fails to indicate correctly to give sound signals; by its means such sound signals are read according to the Morse alphabet, a short sound such as the escapement of the receiving instrument makes when moving a few steps only representing a dot, and a long sound such as the escapement makes when moving over many steps representing a dash.

Having thus described the nature of my Invention and the manner of performing the same, I would have it understood that I claim the construction of electric telegraphs in such manner that current signals and wave signals may be simultaneously transmitted through the same line wire, and may be rendered sensible at the receiving station by separate instruments, the one sensitive to currents of appreciable duration and the other to electric waves or vibrations.

I also claim the construction of electric telegraphs with, at the transmitting station, an instrument capable of originating in the line wire a succession of rapid and regular electric waves, and at the receiving station a strained wire, a tongue, or such like instrument adjusted to vibrate in unison with the electric waves, and being magnetized by them oscillating to and from the pole or poles of a magnet in its vicinity.

I also claim in the construction of electric telegraphs the dividing a conducting wire into sections by instruments which I have called "echocyme," which allow current signals to pass freely but stop wave signals, so that whilst the wire is being used as a whole for through signals the sections into which it is divided may each or all be employed for the transmission of local messages.

I also claim the construction of electric telegraphs with, at the transmitting station, an instrument capable of originating in the line wire a succession of rapid and regular electric waves, and at the receiving station a condenser consisting of thin sheets capable of being agitated by such waves.

I also claim the construction of electric telegraphs with, at the transmitting station, an instrument capable of originating in the line wire a succession of rapid and regular electric waves, and at the receiving station an instrument which on receiving such waves delivers a current of electricity to an indicating or receiving instrument suitable to be worked with ordinary current signals.

I also claim the combination with Dr. Gintl and Frischen's double speaking apparatus of a hollow helix connected between the receiving instrument and the line wire, such helix having rods or pieces of iron inserted into it.

In witness whereof, I, the said Cromwell Fleetwood Varley, have hereunto set my hand and seal, this Seventh day of October, in the year of our Lord One thousand eight hundred and seventy.

CROMWELL F. VARLEY (L.S.)

LONDON: Printed by George Edward Eyre and William Spottiswoode,
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For Her Majesty's Stationery Office.

[192.—50.—4/82.]

(Model.) 2 Sheets—Sheet 1.

A. E. DOLBEAR.

Apparatus for Transmitting Sound by Electricity.

No. 239,742. Patented April 5, 1881.

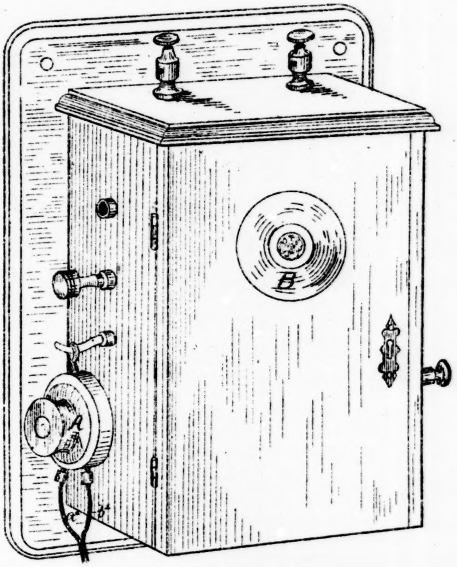

Fig. 1.

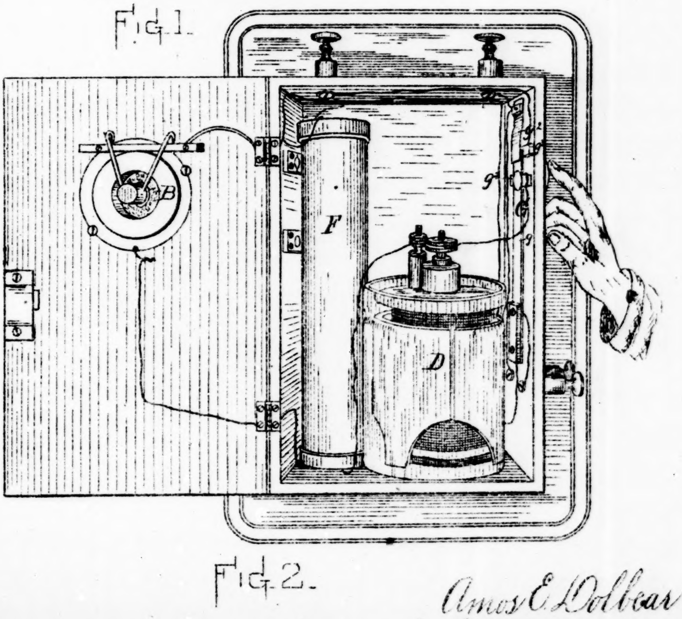

Fig. 2.

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John R. Snow

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(Model.) 2 Sheets—Sheet 2.

A. E. DOLBEAR.

Apparatus for Transmitting Sound by Electricity.

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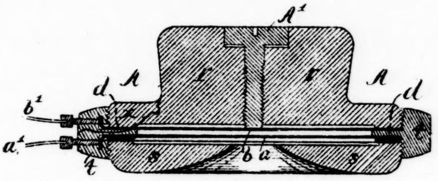


Fig. 3.

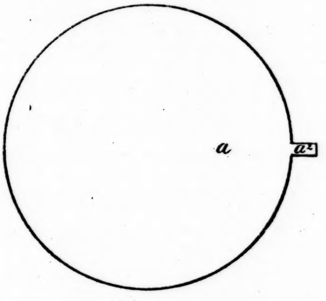


Fig. 4.

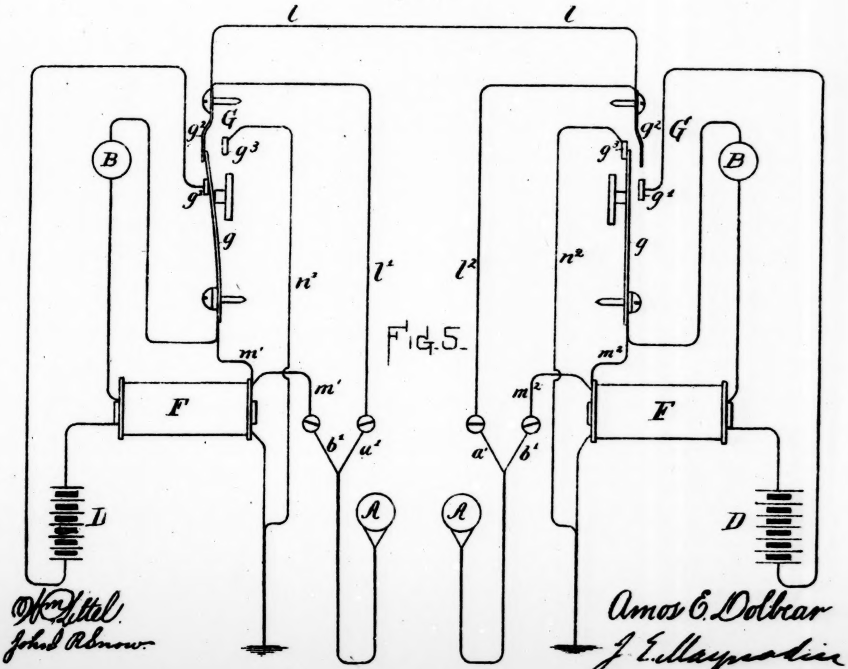


Fig. 5.

John L. R. Snow

Amos E. Dolbear
J. E. Maynadier

UNITED STATES PATENT OFFICE.

AMOS E. DOLBEAR, OF SOMERVILLE, MASSACHUSETTS.

APPARATUS FOR TRANSMITTING SOUND BY ELECTRICITY.

SPECIFICATION forming part of Letters Patent No. 239,742, dated April 5, 1881.

Application filed October 11, 1880. (Model.)

To all whom it may concern:

Be it known that I, AMOS E. DOLBEAR, of Somerville, in the county of Middlesex and State of Massachusetts, have invented a new Apparatus for Transmitting Sound by Electricity, of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawings, making a part hereof, in which—

Figures 1 and 2 are two views of the best form of apparatus for practicing my invention. Fig. 3 is a cross-section, enlarged, of the receiver shown in Fig. 1. Fig. 4 is a plan of one of the plates. Fig. 5 is a diagram illustrating the system.

My invention consists, mainly, in a new mode of transmitting articulate and other sounds by an open circuit.

It also consists in new apparatus for this purpose.

My receiver is based upon the well-known principle that one terminal of an open circuit will attract the other terminal when both are charged; and my invention consists, mainly, in the arrangement of the enlarged terminal of the secondary coil of an induction-coil so that it will be vibrated toward and from the other terminal by variations in the electric state of the coil, and in such a manner as to reproduce sound-vibrations of all qualities, including articulate speech, when the primary circuit of the induction-coil contains a suitable transmitter.

Another feature of my invention relates to the system of connecting two or more receivers and two or more transmitters for practical use; and it consists in the combination of two induction-coils, two receivers, and two transmitters in a novel manner, fully described below.

The best form of my receiver is that shown in elevation in Fig. 1, and in cross-section in Fig. 3.

In Fig. 3 the case of the receiver A is shown as made up of three pieces—a back piece, *r*, an ear-piece, *s*, and an annular connecting-piece, *t*, for connecting the pieces *r* and *s* together.

a b are thin elastic plates, preferably of iron, forming terminals of the secondary coil of an induction-coil. These plates are securely fastened about the edges and brought very near to each other, but not in contact, a thin annulus, *d*, lying between them. This is best effected by forming a thin flange, *d*, on the interior of the connecting-piece, *t*, and placing the terminals *a b* on opposite sides of this flange. The ear-piece *s* of the case holds the terminal *a* in place with the proper tension around the edge to insure mass vibrations of that terminal. The terminal *b* is held in place by the back piece, *r*, of the case. Each of the plates *a* and *b* is formed with a small tongue, a^2, (see Fig. 4,) with which the binding-screws are connected, as shown.

As the section-plane in Fig. 3 will pass through but one of the binding-screws, (that for the wire a',) the receiver is shown broken away at *x*, in order to show the binding-screw for the wire b'. Both are shown in Fig. 1. One of the binding-screws connects with plate *a*, the other with plate *b*. By the use of the tongues an even pressure around the whole edge of the plate is possible.

The adjustment of the instrument is effected by the screw A'; and this screw, by contact upon the back plate, *b*, prevents any vibrations of that plate which interfere with the proper vibrations of the front plate, *a*.

My system requires electricity of a very high electro-motive force, and this is best obtained by means of a secondary coil with a high resistance, the best results having been obtained from four or five thousand ohms of No. 36 copper wire.

Transmitters such as are in common use will answer with my receiver; but the best form of transmitter is that shown in the drawings, (which is not here described, as it forms the subject of an application for a patent filed by me May 31, 1880.)

The main advantages of my new system over all others known to me are, that it is not appreciably affected by ordinary induced currents on the line, it has no magnet to deteriorate, the adjustment is more simple and is not affected by barometric and hygrometric variations, and it lacks the fine-wire helix of the common receiver, which is very liable to get out of repair. It is very efficient also on very long lines.

The best system for the practical use of my invention is illustrated in the diagram, Fig. 5, and the best form of apparatus is that shown in Figs. 1 and 2. In these figures, A represents the receivers, B the transmitters, D the batteries, F the induction-coils, and G switches.

The transmitter B and battery D are in the circuit with the primary coil of the induction-coil F, and this circuit is completed, when the transmitter is to be used, by throwing over the member *g* of switch G until it makes contact with the member g', thereby completing the battery-circuit through the transmitter and primary coil. The electricity induced in the secondary coil affects the plates in the distant receiver by means of that branch of wire m' which extends from one end of the secondary coil to member *g* of switch G, members *g* and g^2 of switch G, the line-wire *l*, which is a continuation of member g^2 of switch G, wire l^2, which is a branch of line-wire *l*, receiver-wires a' b', wire m^2, members *g* g^3 of switch G, wire n^2, to earth, thus cutting out the receiver at the sending-station (on the left of the diagram) and the secondary coil on the right of the diagram.

When the sending-station is at the right of the diagram, the switch G at the right will be arranged as is the switch G at the left, and the receiver at the left is electrified by means of wire l', receiver-wires a' b', (at the left of the diagram,) wire m', members *g* g^3 of switch G, (at the left of the diagram,) wire n', to earth.

The switch G is composed of two springs, *g* g^2, and two stops, g' g^3, arranged as shown, so that when spring *g* is brought in contact with stop g' it will also be in contact with spring g^2, and when spring *g* is in contact with stop g^3 it will be out of contact with both spring g^2 and stop g'. One end of the secondary coil on the left of the diagram is connected with spring *g* on the left of diagram by means of one branch of wire m', and with receiver-wire b' on the left of diagram by means of the other branch of wire m', and one end of the secondary coil on the right of the diagram is connected with spring *g* on the right of diagram by means of one branch of wire m^2, and with receiver-wire b' on the right of the diagram by means of the other branch of wire m^2.

I am aware of the apparatus mentioned as used by Dr. Wright in "Ferguson's Electricity," published by William and Robert Chambers, of London and Edinburgh, in 1867, pages 258 and 259, in which two sheets of paper silvered on one side were placed back to back and connected with the two ends of an induction-coil, the primary circuit of which contained a Reis transmitter; and I disclaim that apparatus. My receiver differs from it in that the sounds transmitted are reproduced by the mass vibrations of one of the terminals, while in the Wright receiving apparatus the sound produced was mainly, if not altogether, due to molecular motion, and not to mass vibrations. Moreover, Wright's sheets of silvered paper were so arranged that each would damp any mass vibrations of the other; and in his apparatus any slight mass vibrations, even if not wholly damped, would be necessarily so irregular as to be worthless as a means of reproducing sounds. The fact, also, that the mass vibrations of each sheet damped those of the other sheet would make all the mass vibrations worthless for this purpose.

I am also aware of English Patents No. 4,934 of 1877 and No. 2,396 of 1878, and disclaim all therein shown.

What I claim as my invention is—

1. The receiver above described, consisting of the plates *a b*, mounted in case *r s t*, and separated by the annulus *d*, in combination with induction-coil F, substantially as described.

2. In combination, two induction-coils, the primary of each containing a battery, D, and transmitter B, and the secondary circuits, each containing receiver A, by means of switches G, consisting of members *g* g' g^2 g^3, whereby the receiver at the sending-station and coil at the receiving-station are switched out of the line, substantially as described.

AMOS E. DOLBEAR.

Witnesses:

W. A. COPELAND,

J. R. SNOW.

(Model.)

A. E. DOLBEAR.

Mode of Transmitting Sound by Electricity.

No. 240,578. Patented April 26, 1881.

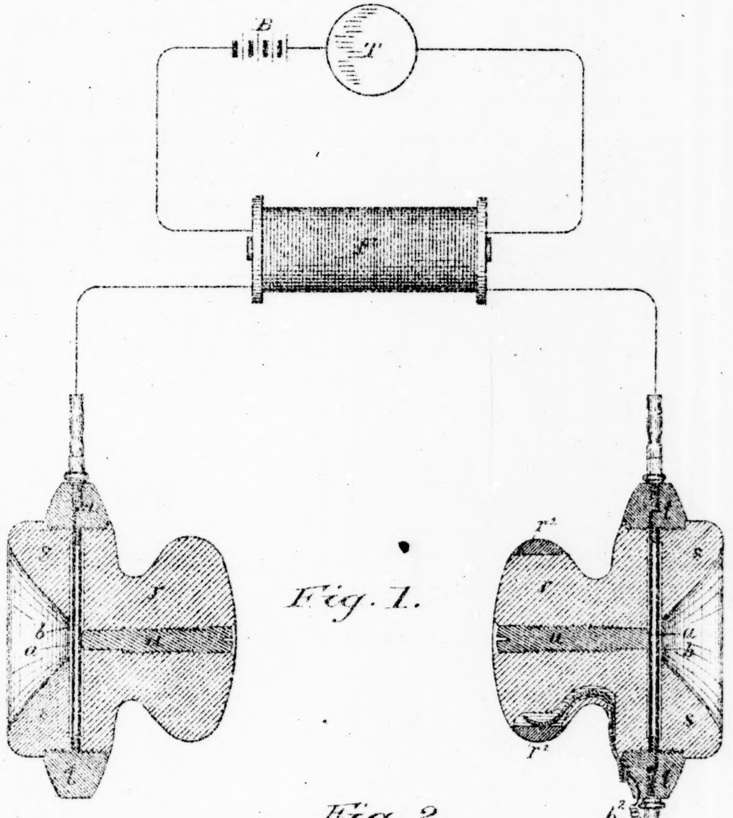
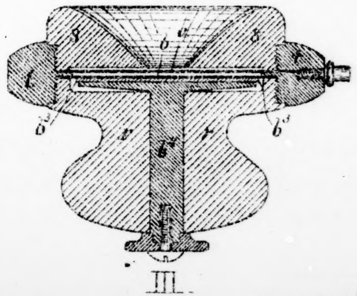


Fig. 1.

Fig. 2.



Witnesses:

Wm. Zittel

John R. Snow

Inventor.

Amos E. Dolbear

by J. E. Maynadier

UNITED STATES PATENT OFFICE.

AMOS E. DOLBEAR, OF SOMERVILLE, MASSACHUSETTS.

MODE OF TRANSMITTING SOUND BY ELECTRICITY.

SPECIFICATION forming part of Letters Patent No. 240,578, dated April 26, 1881.

Application filed February 24, 1881. (Model.)

To all whom it may concern:

Be it known that I, AMOS E. DOLBEAR, of Somerville, in the county of Middlesex and State of Massachusetts, have invented a new Mode of Transmitting Sounds by Electricity, of which the following is a full, clear, concise, and exact description, reference being had to the accompanying drawings, making a part hereof.

My invention consists, mainly, in a new mode of transmitting articulate and other sounds by an open circuit.

It also consists in new apparatus for this purpose.

My receiver is based upon the discovery that one terminal of an open circuit will attract and be attracted by a neighboring body when the terminal is charged.

Figure 1 shows two modifications of my receiver, in section, connected in circuit with a transmitter and induction-coil. Fig. 2 shows another modification of my receiver.

Three forms of my receiver are shown in the drawings. In each the casing is formed of three pieces, *r* being the back-piece, *s* the ear-piece, and *t* the connecting-piece which connects *r* and *s* together. The plate *a* of receiver I is a thin elastic disk, preferably of iron, the vibrations of which reproduce the sound which causes the diaphragm of the transmitter T to vibrate, T representing a transmitter of suitable construction, the form preferred being that shown in my application for a patent filed May 31, 1880, the transmitter T and the battery B being in circuit with the primary coil, as will be clear without further description.

In receiver I the plate *a* is one terminal of the secondary coil F, and any change in the electrical state of coil F varies the potential of this plate *a* in receiver I and causes it to attract plate *b*, which is mounted close to, but not in contact with, plate *a*; but as plate *b* in receiver I is so mounted that it cannot vibrate, plate *a* will vibrate as its potential varies. In receiver I the plate *b* and back-piece *r* and adjusting-screw *u* are all of metal.

It will be seen that neither the plate *b* nor back-piece *r* nor screw *u* of receiver I is connected to the coil F, but that only one terminal of coil F—viz., plate *a*—forms any part of the receiver I. The plate *b* may be made in one piece with back-piece *r*, but for purposes of adjustment is best made as shown.

The force of the attraction between the charged terminal *a* and any neighboring body is slight, unless the neighboring body be many times larger than the terminal and itself capable of being readily electrified, and for this reason, when the neighboring body is a plate, (as it is best made for purpose of adjustment,) it should be electrically connected with a larger body. Consequently the back-piece *r* of the case of receiver I is made of metal, and is in metallic contact with plate *b*. The neighboring body, which is attracted by plate *a* in receiver I, (being, in fact, the plate *b*, piece *r* and screw *u*, which are all of metal and in metallic contact,) acts as one body in this receiver I; but, as will be clear, the back-piece *r*, plate *b*, and screw *u* may be one single piece of metal, and some other provision be made for the necessary adjustment.

In receiver I I the terminal *a* is mounted upon back-piece *r*, so that it cannot vibrate, and must therefore be insulated. Consequently the back-piece *r* is made of hard rubber. The plate *b*, which is the neighboring body in receiver I I, is connected by the wire b^2 with a metal band, r^2, upon back-piece *r*, in order to increase the attractive force due to the electrification of a greater mass than plate *b*, and without interfering with the proper vibration of plate *b*, which, in receiver I I, vibrates as the potential of terminal *a* varies.

It will be clear that either of the plates *b* may be grounded, and thereby increase the electrification of these plates; but it is not necessary to ground either of them, and the audibility of the sounds reproduced is practically as great when the back-piece of the receiver is held in the hand as when the plates *b* are both grounded; and it makes no difference whatever whether both be grounded or only one. In other words, receiver I will reproduce articulate and other sounds, even if back-piece *r* be of hard rubber or other non-conductor and plate *b* be wholly disconnected from coil F, but the sounds reproduced are faint, although distinct and audible. The sounds will be louder if the piece *r* be of metal, as above described, or if the plate *b* or metallic piece *r* be grounded; but the difference is very slight, the sounds being practically as loud when the metal piece *r* is used as when the plate *b* is grounded. And so of receiver I I the sounds are distinct and audible when wire b^5 and metal band r^2 are omitted, but louder when metal band r^2 and wire b^2 are used, as shown, or when plate *b* of receiver I I is grounded. Moreover, the reproduction of sound by receiver I does not depend at all upon the grounding of any part of receiver I I, for receiver I will act with plate *b* of receiver I I not grounded precisely as it does when plate *b* of receiver I I is grounded, and receiver I I will act when plate *b* of receiver I is not grounded precisely as it acts when that plate of receiver I is grounded.

In my application filed October 31, 1880, I have described a receiver in which both the plates *a* and *b* are connected with the coil F, and I therefore disclaim in this application any receiver having both the plates connected with that coil, my present invention consisting in a receiver in which only one terminal of the coil is used, as above explained.

Instead of making plate *b* of metal and connecting it metallically with back-piece *r* or band r^2, it may be made of any non-conductor, and in this case the increased loudness is produced by electrifying plate *b* before it is put in place; or, as shown in receiver I I I, where *b* is a rubber plate, and b^3 is a disk of felt fast to the hard-rubber support b^4, which is turned by the thumb and finger to electrify rubber plate *b* by friction.

What I claim as my invention is—

In combination, a primary coil in circuit with battery B and transmitter T, and a secondary coil with its enlarged terminal *a* mounted in case *r s t*, and arranged near plate *b*, plate *b* being also mounted in case *r s t*, but not connected with the secondary coil, all substantially as described.

AMOS E. DOLBEAR.

Witnesses:
J. E. MAYNADIER,
JOHN R. SNOW.

The following is a copy of the opinion of the court in said cause in accordance with which a temporary injunction was granted January 24, 1883.

Circuit Court of the United States,

DISTRICT OF MASSACHUSETTS.

No. 1628.
EQUITY DOCKET.

AMERICAN BELL TELEPHONE COMPANY
v.
AMOS E. DOLBEAR, ET AL.

BEFORE GRAY AND LOWELL, JJ.

OPINION OF THE COURT.

[JANUARY 24, 1883.]

GRAY, J. Few legal rules have been oftener misunderstood and misapplied than the maxim that you cannot patent a principle. But the confusion on this subject has been so effectually cleared up by the recent judgment of the Supreme Court, delivered by Mr. Justice Bradley, in *Tilghman* v. *Proctor*, 102 U. S., 707, that it will be sufficient for the purposes of this case to state the conclusions there announced.

There can be no patent for a mere principle. The discoverer of a natural force or a scientific fact cannot have a patent for that. But if he invents for the first time a process by which a certain effect of one of the forces of nature is made useful to mankind, and fully describes and claims that process, and also describes a mode or apparatus by which it may be usefully applied, he is, within the meaning, and the very words, of the patent law, "a person who has invented or discovered any new and useful art;" and he is entitled to a patent for the process of which he is the first inventor, and is not restricted to the particular form of mechanism or apparatus by which he carries out that process. Another person, who afterwards invents an improved form of apparatus, embodying the same process, may, indeed, obtain a patent for his improvement, but he has no right to use the process, in his own or any other form of apparatus, without the consent of the first inventor of the process.

It was decided by this court in *American Bell Telephone Co.* v. *Spencer*, 8 Fed. Rep., 509, and it is not denied by the present defendant, that Bell is the first inventor of a speaking telephone. The only controversy is of the extent of his patent.

The draftsman of the specification has exhibited as clear and accurate a comprehension of the rules of the patent law as the inventor has of the force of nature with which he was dealing, and of the means by which he reduced that force to a practical use.

The patent is clearly not intended to be limited to a form of apparatus, but embraces a method or process. This is apparent upon the face of the specification.

The inventor begins by saying: "My present invention consists in the employment of a vibratory or undulatory current of electricity in contradistinction to a merely intermittent or pulsatory current, and of a method of and apparatus for producing electrical undulations upon the line wire."

After describing the advantages of an undulatory current, resulting from gradual changes of intensity, over a pulsatory current caused by sudden changes of intensity, he says: "It has long been known that when a permanent magnet is caused to approach the pole of an electro-magnet a current of electricity is induced in the coils of the latter, and that when it is made to recede a current of opposite polarity to the first appears upon the wire. When, therefore, a permanent magnet is caused to vibrate in front of the pole of an electro-magnet an undulatory current of electricity is induced in the coils of the electro-magnet, the undulations of which correspond, in rapidity of succession, to the vibrations of the magnet, in polarity to the direction of its motion, and in intensity to the amplitude of its vibration;" or, as he afterwards repeats in fuller language: "Electrical undulations, induced by the vibration of a body capable of inductive action, can be represented graphically, without error, by the same sinusoidal curve which expresses the vibration of the inducing body itself, and the effect of its vibration upon the air; or, as above stated, the rate of oscillation in the electrical current corresponds to the rate of vibration of the inducing body—that is, to the pitch of sound produced; the intensity of the current varies with the amplitude of the vibration—that is, with the loudness of the sound; and the polarity of the current corresponds to the direction of the vibrating body—that is, to the condensations and rarefactions of air produced by the vibration."

He further says: "There are many ways of producing undulatory currents of electricity, dependent for effect upon the vibrations or motions of bodies capable of inductive action. A few of the methods that may be employed I shall here specify. When a wire, through which a continuous current of electricity is passing, is caused to viabrate in the neighborhood of another wire, an undulatory current of electricity is induced in the latter. When a cylinder, upon which are arranged bar magnets, is made to rotate in front of the pole of an electro-magnet, an undulatory current of electricity is induced in the coils of the electro-magnet.

"Undulations are caused in a continuous voltaic current by the vibration or motion of bodies capable of inductive action, or by the vibration of the conducting wire itself in the neighborhood of such bodies. Electrical undulations may also be caused by alternately increasing and diminishing the resistance of the circuit, or by alternately increasing and diminishing the power of the battery. The internal resistance of a battery is diminished by bringing the voltaic elements nearer together, and increased by placing them farther apart. The reciprocal vibration of the elements of a battery, therefore, occasions an undulatory action in the voltaic current. The external resistance may also be varied. For instance, let mercury or some other liquid form part of a voltaic circuit, then the more deeply the conducting wire is immersed in the mercury or other liquid, the less resistance does the liquid offer to the passage of the current. Hence the vibrations of the conducting wire in mercury or other liquid included in the circuit occasions undulations in the current. The vertical vibration of the elements of a battery in the liquid in which they are immersed produces an undulatory action in the current by alternately increasing and diminishing the power of the battery.

"In illustration of the method of creating electrical undulations, I shall show and describe one form of apparatus for producing the effect. I prefer to emply for this purpose an electro-magnet, A, Fig. 5, having a coil upon only one of its legs *b*. A steel-spring armature, *c*, is firmly clamped by one extremity to the uncovered leg *d* of the magnet, and its free end is allowed to project above the pole of the covered leg. The armature *c* can be set in vibration in a variety of ways, one of which is by wind, and, in vibrating, it produces a musical note of a certain definite pitch. When the instrument A is placed in a voltaic circuit, *g b e f g*," (in which *b* represents the covered leg of the first electro-magnet; *f* represents the covered leg of another similar electro-magnet, I, whose uncovered leg is marked *h;* and *g* and *e* represent the two points of the voltaic circuit midway of the wire connecting the two magnets) "the armature *c* become magnetic, and the polarity of its free end is opposed to that of the magnet underneath. So long as the armature *c* remains at rest no effect is produced upon the voltaic current; but the moment it is set in vibration to produce its musical note, a powerful inductive action takes place, and electrical undulations traverse the circuit *g b e f g*. The vibratory current passing through the coil of the electro-magnet *f* causes vibration in its armature *h*, when the armatures *c h* of the two instruments A I are normally in unison with one another; but the armature *h* is unaffected by the passage of the undulatory current when the pitches of the two instruments are different."

Then, after showing how two or more telegraphic signals or messages may be sent simultaneously over the same circuit without interfering with one another, he adds: "I desire here to remark that there are many other uses to which these instruments may be put, such as the simultaneous transmission of musical notes, differing in loudness as well as in pitch, and the telegraphic transmission of noises or sounds of any kind.

"When the armature *c*, Fig. 5, is set in vibration, the armature *h* responds not only in pitch but in loudness. Thus, when *c* vibrates with little amplitude, a very soft musical note proceeds from *h;* and when *c* vibrates forcibly, the amplitude of the vibration of *h* is considerably increased, and the resulting sound becomes louder."

He proceeds to say: "One of the ways in which the armature *c*, Fig. 5. may be set in vibration has been stated above to be by wind. Another mode is shown in Fig. 7, whereby motion can be imparted to the armature by the human voice or by means of a musical instrument.

"The armature *c*, Fig. 7, is fastened loosely by one extremity to the uncovered leg *d* of the electro-magnet *b*, and its other extremity is attached to the centre of a stretched membrane, *a*. A cone, A, is used to converge sound-vibrations upon the membrane. When a sound is uttered in the cone, the membrane *a* is set in vibration, the armature *c* is forced to partake of the motion, and thus electrical undulations are created upon the circuit E *b e f g*. These undulations are similar in form to the air-vibrations caused by the sound, that is, they are represented graphically by similar curves. The undulatory current passes through the electro-magnet *f* influences its armature *h* to copy the motion of the armature *c*. A similar sound to that uttered into A is then heard to proceed from L."

The reference to figure 7 will be better understood by repeating, slightly amplified, Judge Lowell's explanation in *Spencer's case.* A cone of pasteboard or other suitable material, A, has a membrane, *a*, stretched over its smaller end; at a little distance is the armature *c*, consisting of a piece of iron magnetized by the coil of the electro-magnet *b*, through which is passing a current of electricity. When sounds are made at the mouth of the cone A, the membrane *a* vibrates like the drum of a human ear; and the armature *c*, which is directly in front of the magnet *b*, vibrates with this membrane, and its movements cause pulsations of electricity like those of the air which excited the membrane to pass over the wire *e*, which stretches to another similar magnet *f*, and cone L, with its membrane, and its armature, *h*. The second armature and membrane take up the vibrations and make them audible by repeating them into the second cone L, which translates them into vibrations of the air. In practice, a metallic diaphragm or disc is often substituted for each membrane.

The inventor adds the explanation: "In this specification the three words 'oscillation,' 'vibration' and 'undulation' are used synonymously, and in contradistinction to the terms 'intermittent' and 'pulsatory.' By the term 'body capable of inductive action,' I mean a body which, when in motion, produces dynamical electricity. I include in the category of bodies capable of inductive action brass, copper and other metals, as well as iron and steel."

His fifth and final claim is of "the method of and apparatus for transmitting vocal or other sounds telegraphically, as herein described, by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds, substantially as set forth."

In this claim, as throughout the specification, the word "method" is evidently used, not as synonymous with "mode" or "apparatus," but as equivalent to "process;" just as it was used by Chief Justice Taney, delivering the judgment of the majority of the court, in *Morse* v. *O'Reilly*, 15 How., 62, 117, as well as by Mr. Justice Grier (who dissented in *Morse* v. *O'Reilly*) in delivering the unanimous judgment in *Corning* vs. *Burden*, 15 How., 252, 267. And the invention claimed is not merely the apparatus described, but also the general process or method, by which the wind, or a musical instrument, or the human voice, produces in a current of electricity a succession of electrical disturbances, not sudden and intermittent or pulsatory, but gradual, oscillatory, vibratory or undulatory, so as to give out at the farther end of the conducting wire sounds exactly corresponding in loudness, in pitch, and in tone, character or quality, to the sounds committed to it at the nearer end.

The opinion in *Spencer's case* clearly points out that "Bell discovered a new art—that of transmitting speech by electricity—and has a right to hold the broadest claim for it which can be permitted in any case," and "the invention is nothing less than the transfer to a wire of electrical vibrations like those which a sound has produced in the air," and that his patent, while not covering the abstract principle, without regard to means, of transmitting speech by electricity yet is not limited to a particular form of apparatus, but includes the process or method (using the two words as equivalent), the essential elements of which are "the production of what the patent calls undulatory vibrations of electricity to correspond with those of the air, and transmitting them to a receiving instrument capable of echoing them."

The evidence in this case clearly shows that Bell discovered that articulate sounds could be transmitted by undulatory vibrations of electricity, and invented the art or process of transmitting such sounds by means of such vibrations. If that art or process is (as the witnesses called by defendant say it is) the only way by which speech can be transmitted by electricity, that fact does not lessen the merit of his invention, or the protection which the law will give to it.

The mode or apparatus by which Bell effects his purpose is, by using an electro-magnet in the transmitter, and another electro-magnet in the receiver. But the essence of his invention consists not merely in the form of apparatus which he uses, but in the general process or method of which that apparatus is the embodiment.

Dolbear likewise uses an electro-magnet in the transmitter; and both his method and his apparatus, as is admitted in his own affidavit, are substantially like Bell's until he comes to the receiver. For the magneto-receiver, Dolbear substitutes a condenser receiver, consisting of two thin metal diaphragms or discs, of about the size and thickness of those used in an ordinary Bell telephone, separated by a very thin air space, one or both discs connected with the conducting wire, and the speaking disc, if not so connected, otherwise charged with electricity; so that, as the varying currents flow into and out of this condenser, the two discs attract one another more or less strongly, and thereby vibrations are set up which correspond to the vibrations of the original sound.

The main differences on which the defendants rely is, that Bell uses what is called dynamic electricity, producing by its motion an electric current; while Dolbear, in his receiver, uses what is called static electricity, producing, while at rest, electrical attraction. And the learned counsels for the defendants illustrate the distinction thus: "It was known, long before Bell's method, that electricity had two properties, very much as water has two properties, namely, first, pressure or head, or that property which tends to make it flow, and which can exist by itself only in the case of an insulated and charged body, or a reservoir of water; and, secondly, that dynamic property arising from its motion, and which never can exist by itself, but depends upon the quantity in motion and the rate of motion. This is not an absolutely exact way of expressing it, for the reason that electricity is not a fluid; but, were it a fluid, the statement would be entirely exact."

It does not appear to us to be important to determine whether, in scientific exactness, the varying influences of static electricity may properly be called currents; or whether the two properties of electricity differ in kind and in substance, or only in degree, or in the form of manifestation and application; or whether the force of the property which tends to make a fluid, when stationery, change its place and flow, is different in kind from that which it exerts, when changing its place and flowing—in short, whether the power of the pressure of water in a reservoir is different in kind from water power in a stream or current.

Whatever name be given to the property, or the manifestation, of the electricity in the defendants' receiver, the facts remain that they avail themselves of Bell's discovery that undulatory vibrations of electricity can intelligibly and accurately transmit articulate speech, as well as of the process which Bell invented, and by which he reduced his discovery to practical use; that they also copy the mode and apparatus by which he creates and transmits the undulatory electrical vibrations, corresponding to those of the air; and that in the plate charged with electricity, which they have substituted for the magnetic coil in the receiver, the charge constantly varies in accordance with the principle which Bell discovered, and by means of the undulatory current caused by the process and in the mode which he invented and patented.

The defendants have therefore infringed Bell's patent by using his general process or method, and should be restrained by injunction from continuing to do so; and it is unnecessary, for the purposes of this decision, to consider whether the defendants' apparatus is a substantial equivalent of the plaintiff's, or whether it is an improvment for which Dolbear might himself be entitled to a patent.

Temporary injunction ordered.

The following is a copy of the opinion of the court in said cause, in accordance with which the final decree was entered September 8, 1883:

Circuit Court of the United States,

DISTRICT OF MASSACHUSETTS.

No. 1628.
Equity Docket.

AMERICAN BELL TELEPHONE COMPANY
v.
AMOS E. DOLBEAR ET AL.

OPINION OF THE COURT.

[August 25, 1883.]

Lowell, J. The final hearing in this case was hardly more than a form, because the two questions which are raised by the record have been decided in favor of the plaintiff on motions for preliminary injunction which were prepared and argued with unusual thoroughness. These questions are: "Whether the telephone described by Reiss anticipates the Bell telephone," and "Whether Dolbear's apparatus infringes Bell's patent?"

1. I decided in *American Bell Telephone Co.* v. *Spencer*, 8 Fed. Rep., 509, that Reis had not described a telephone which anticipated Bell's invention. The same point has since been decided in the same way in England. *United Telephone Co.* v. *Harrison*, 21 Ch. D., 720. It is admitted in the present case that the Reis instrument, if used as he intended to use it, can never serve as a speaking telephone, because the current of electricity is constantly broken; and it is essential for the transmission of speech that the current should not be broken. The defendant now testifies that the Reis instrument can

be made to transmit speech, under some circumstances, if operated in the way which Bell has shown to be necessary. In 1877 he several times expressed the opinion that Bell made the invention and that Reis did not make it. The experiment made in the presence of counsel, which was intended to prove the correctness of the defendants' present opinion, was an utter failure. But if it be admitted that the Reis instrument is capable of such use, to a very limited extent, and after a change in its proportions, and when used in a way which the inventor did not intend, still, I am of opinion that it was not an anticipation of Bell. The case of *Clough* v. *Barker*, 106 U. S., 166, would apply to such a state of facts. That case, undoubtedly, is an exceptional one, and its doctrine must be applied with much reserve; but when so applied it will occasionally be useful. It is, that if a certain machine or organization is capable of a certain use only under unusual, and, as I may say, abnormal conditions, so that a person of skill and knowledge in the art to which it relates, or a person using the machine, would not, unless by accident, discover that it was capable of such a mode of operation, it shall not be considered an anticipation of a machine or organization which is founded upon such mode of operation.

2. At the former hearing in this case before Mr. Justice Gray and me we decided that the defendant, whatever the merits of his telephone may be, employs in it a part, at least, of Bell's process. No additional evidence has been given at the final hearing, unless a further explanation of that already given may be called additional, and I remain of the opinion expressed by the presiding justice at that time: *American Bell Telephone Co.* v. *Dolbear et al.*, 15 Fed. Rep., 448.

Decree for the Complainant.

The following is the opinion of the court upon the settlement of the final decree, namely:

Circuit Court of the United States,

DISTRICT OF MASSACHUSETTS.

No. 1628.
Equity Docket.
AMERICAN BELL TELEPHONE COMPANY
v.
AMOS E. DOLBEAR ET AL.

OPINION OF THE COURT.

[Sept. 26, 1883.]

Lowell, J. On settlement of the decree it appears that through a misunderstanding of the arguments I failed to consider the questions arising under Bell's second patent, No. 186787, dated January 30, 1877, and in order that the appeal on the first and more important patent may not be delayed it has been agreed that no decree shall be made in respect to the said second patent.

United States of America, } *ss:*
Massachusetts District,

I, John G. Stetson, clerk of the circuit court of the United States for the first circuit and district of Massachusetts, certify that the foregoing is a true copy of the record and of all proceedings, including the opinions of the court, in the cause in equity entitled *American Bell Telephone Company, Complainants*, v. *Amos E. Dolbear et al., Defendants*, in said circuit court determined.

In testimony whereof I have hereunto set my hand and affixed the seal of said circuit court at Boston, in said district, this fifth day of October, in the year of our Lord one thousand eight hundred and eighty-three and of the Independence of the United States the one hundred and eighth.

JOHN G. STETSON, *Clerk.*

[Seal of the Circuit Court, Massachusetts.]

Know all men by these presents, that we, Amos E. Dolbear, of the the city of Somerville; Francis M. Holmes, of the city of Boston, both in the State of Massachusetts, and Henry B. Metcalf, of the city of Pawtucket, State of Rhode Island, as principals; and Cyrus Wakefield, of Wakefield, and Wm. A. Haskell, of Boston, both in the State of Massachusetts, as sureties, are held and firmly bound unto the American Bell Telephone Company, a corporation duly established under the laws of the Commonwealth of Massachusetts, in the full and just sum of fifteen hundred dollars, to be paid to the said American Bell Telephone Company, its certain attorney, successors, or assigns; to which payment, well and truly to be made, we bind ourselves, our heirs, executors, and administrators, jointly and severally, by these presents.

Sealed with our seals and dated the fifth day of October, in the year of our Lord one thousand eight hundred and eighty-three.

Whereas, lately at a circuit court of the United States for the district of Massachusetts, in a suit in equity depending in said court between said American Bell Telephone Company, complainants, and said Amos E. Dolbear, Francis M. Holmes, and Henry B. Metcalf, defendants, decree was rendered against the said defendants, and the said defendants having obtained an appeal to remove the said cause to the Supreme Court of the United States to reverse the decree in the aforesaid suit, and a citation directed to the said complainants citing and admonishing them to be and appear at a Supreme Court of the United States to be holden at Washington on the second Monday of October next.

Now the condition of the above obligation is such that if the said defendants shall prosecute their said appeal to effect and answer all damages and costs, if they fail to make their plea good, then the above obligation to be null and void; otherwise to remain in full force and virtue.

HENRY B. METCALF. [L. S.]
FRANCIS M. HOLMES. [L. S.]
A. E. DOLBEAR. [L. S.]
C. WAKEFIELD. [L. S.]
WM. A. HASKELL. [L. S.]

Signed, sealed, and delivered in presence of—
IDA E. HOLMES.

Approved.
THOMAS L. NELSON,
U. S. Dist. Judge.

A true copy of the bond taken by the judge at the time of allowing the appeal named in said bond, which bond is on file in the office of the clerk of the circuit court of the United States for the first circuit and district of Massachusetts.

Attest: JOHN G. STETSON,
Clerk C. C. U. S., Mass. Dist.

[Endorsed on cover:] Massachusetts C. C. U. S. No. 113. Amos E. Dolbear, Francis M. Holmes, and Henry B. Metcalf, appellants, *vs.* The American Bell Telephone Company. Filed 8th October, 1883.